1990

Field investigations of sediment accumulation rates in the nearshore zone of Point Pelee, Ontario.

Lorie Ann. Libby
University of Windsor

FIELD INVESTIGATIONS OF SEDIMENT ACCUMULATION RATES IN THE NEARSHORE ZONE OF POINT PELEE, ONTARIO

by

Lorie Ann Libby

A Thesis submitted to the
Faculty of Graduate Studies and Research
through the Department of Geography
in Partial Fulfillment of the
requirements for the Degree
of Master of Arts at the
University of Windsor

Windsor, Untario, Canada

1990

ISBN 0-315-60983-4

Libby, Lorie

Field Investigations of Sediment Accumulation Rates in the Nearshore zone of Point Pelee

- due to lack of pagination, please omit Appendix III, pp. 91-113.

Approved by:

Dr. A.G. Phipps, Chairman
Department of Geography

Dr. C. Lakhan
Department of Geography

Dr. P. LaValle
Department of Geography

Dr. J.A. McCorquodale
Department of Civil and Env. Engineering

ABSTRACT

Field Investigations of Sediment Accumulation Rates in the Nearshore Zone of Point Pelee, Ontario

by
Lorie Ann Libby

In this investigation, sediment accumulation rates were estimated in the nearshore zone of Point Pelee. Five cylindrical sediment traps were designed and installed in nearshore locations at various depths. The traps were sampled bi-weekly for a period of four months during the summer of 1988. The contents were weighed, analyzed and compared with the results of a computer program which predicted wave height and wave period on Lake Erie.

Initially, the traps were a reasonable means to estimate sediment accumulation rates. The results coincided with previous theories that the west shore of Point Pelee was responsible for more sediment transport than the east shore was. However, the wave program was found to underestimate considerably nearshore conditions due to deepwater wave assumptions implicit in the model. Although this was the best program available, actual wave height and wave period could not be estimated. The general trends that the program generated were reliable. For this reason, sediment traps were found to be useful for investigating sediment accumulations. However, the results could only be related to trends in increasing wave height and wave period and

not to actual amounts of sediment present as a result of unknown underestimation by the wave program.

ACKNOWLEDGEMENTS

I would like to thank my advisors, Dr. LaValle, and Dr. McCorquodale, for their input into this thesis.

The support and advice of Rick Dumala and Ron Welch is also appreciated. Without their help, this would not be completed.

I would like to thank my parents for their endless patience and also their financial commitment to my graduate thesis. Without their help, this project would have never materialized.

I owe my brother a great deal for the use of his boat during the summer of 1988. The staff and administration of Point Pelee National Park are also acknowledged for their complete co-operation with this project.

I am indebted to Mr. Alan King for his scuba diving skills.

Finally, I would like to thank A.J. and Claude for tolerating my volatile behaviour over the past two years.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

CHAPTER 1

1.0 NATURE OF THE STUDY

1.1 INTRODUCTION

Beaches are merely piles of loose sand or shingle, and yet they manage to remain intact on coastlines where the waves can reduce concrete seawalls to rubble in a very short time. The secret of their geomorphic success lies of course in this very fact - that they are only loose sand. The beach is able to maintain itself in a dynamic equilibrium with its environment due to the inherent mobility of its sediments (Pethick, 1984). Their geomorphological characteristics are the result of wind and wave energy processes acting on terrestrial and lacustrine materials. Beach materials are settled, transported, resuspended, convected or diffused to generate the resultant spatial and temporal patterns reflected in the nearshore zone. The interaction of process and result behave according to physical laws that are considered constant throughout time. However, the results of the complex interactions of several processes in the nearshore zone are not readily definable (Buller and McManus, 1976).

1.2 PROBLEM UNDER STUDY

While much research has been carried out on the hydrodynamics of the nearshore zone, research on the sediment transport mechanisms is still at a preliminary stage (Deigard et al., 1986). It is therefore necessary to conduct sediment transport studies in order to understand the volume, masses and transport rates of sediments in nearshore areas. Sedimentary analyses have been investigated in Lake Erie in the past by several researchers (for example, Lewis, 1966; Skafel, 1975; St.Jacques and Rukavina, 1976; Coakley, 1978,1980; Lee et al., 1981; Rathke et al., 1981; Nummedal et al., 1984). However, these studies were restricted to analyses of already deposited sediments, and to laboratory simulation of suspended sediment concentrations and settling fluxes.

Eadie et al., (1984) collected sediment trap data over a four year period to estimate the magnitude of resuspended sediments and associated nutrients in southern Lake Michigan. However, his research was directed towards resuspension and benthic chemical compositions rather than sediment transport patterns.

Rosa (1985) investigated seasonal variations in the weekly sedimentation rates of particulate matter in the nearshore zone of Lake Ontario using sediment traps. Rathke et al., (1981) measured accumulation rates and settling fluxes of detrital particles in Lake Erie utilizing data collected via sediment traps. In addition, Rathke et al., (1981) and Rosa (1985) did not consider sediment accumulation as an indication of sedimentary transportation patterns. Based on previous investigations, it is evident that research is clearly needed in the measurement of sediment masses and settling rates relative to each other in order to develop explanations for sediment transportation patterns. Sediment masses, accumulation rates and settling fluxes can be taken into account to reveal sediment conditions and deposition patterns in the nearshore region.

1.3 OBJECTIVES

Although several investigators have attempted simulation and estimation, there is little quantitative data on sediment transport rates in the Great Lakes region. The literature becomes even more scant when the focus shifts to Lake Erie. Because of the lack of information on actual sediment transport rates, this study will involve collection of sediment masses to determine rates of transportation and deposition reflected through the amount of energy present in the nearshore zone.

This investigation will therefore attempt to:

1. Measure sediment masses and accumulation rates in the nearshore zone.

2. Compare measurements at one site to those at other locations.

3. Compare measurements at one site to measurements taken at that same site over time.

4. Compare measurements taken at various depths of water.

These quantitative and qualitative comparisons can lead to explanations of sediment transport mechanisms and the resultant sediment masses and accumulation rates in the nearshore zone. To fulfil the aforementioned objectives, this study will be conducted in the Point Pelee area.

CHAPTER 2

2.0 THEORETICAL CONSIDERATIONS

2.1 STUDY AREA CHARACTERISTICS

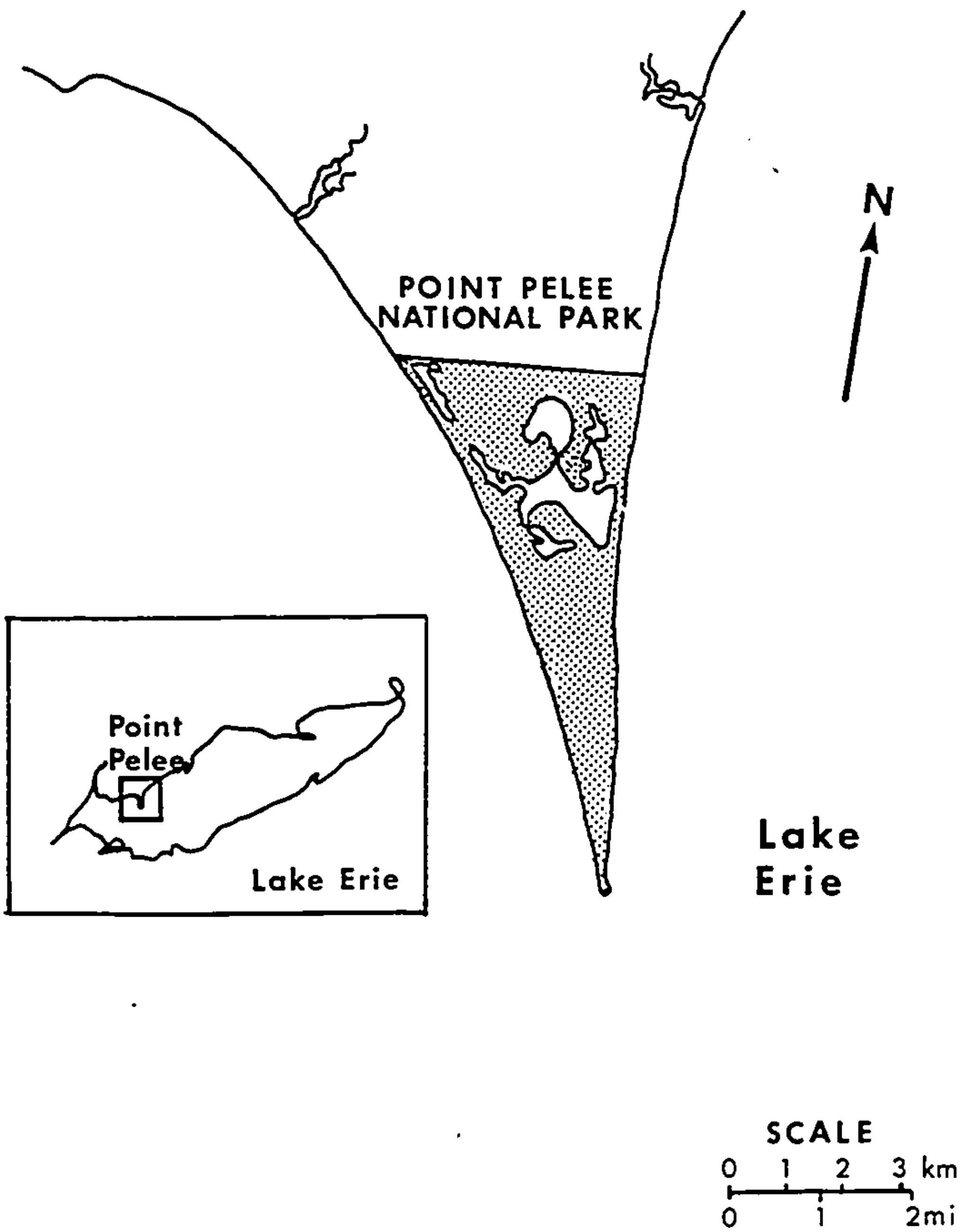
Point Pelee is a cuspate foreland on the northern shore of Lake Erie that formed over 4000 years ago (Figure 1). It is an open system where changes in the tip are the result of a net transfer of sediment from the Point itself to the sand spit and adjacent shoals and possibly up the western shoreline (East, 1976). The west side of the Point is characterized by a distinct change in slope where the nearshore and offshore zones meet (Shaw, 1978). This intersection is termed the "edge of the Pelee rise" (Coakley and Cho, 1972). Shaw (1978) noted a gradual tapering in the width of the western nearshore zone from 0.7 km to 0.5 km (north to south) with single discontinuous bar and trough development occurring, usually less than 0.5 metres. The eastern nearshore zone width ranged from 1 km in the north to 0.8 km at the tip (Shaw, 1978), with some submarine bars present. Coakley (1978) also suggested that the sediments derived from erosional processes at the tip which are not deposited in the shoal area come to rest to the west of the tip in the nearshore zone.

Trenhaile and Dumala (1978) indicated that sediment transport in the nearshore zone of Point Pelee decreases progressively southward. In addition, the authors suggested

FIGURE 1

LOCATION OF STUDY AREA

$41^{0}54'N \quad 82^{0}30'W$



Source: Coakley, 1978

possible local movement of sediments north due to the presence of gravel at the southern portion of the west side of the tip.

Both rip currents and longshore currents resulted in the loss (erosion) and movement of sediment from the shoreline. It appeared that a rip current possibly existed at the tip of Point Pelee with eroded sediment moving offshore to supply the shoal area (Coakley, 1980).

2.2 STUDIES OF SEDIMENT MOVEMENT IN STUDY AREA

There is a paucity of studies pertaining to sediment transport in the nearshore zone of Point Pelee. Preliminary attempts to describe sedimentary processes in this region were put forth by Kindle (1933). He examined the possible sources of sediments, the direction and velocity of currents, the offshore distribution of sediments and two nearshore bottom surveys. From these, he postulated that:

a) Sediments do not move northward toward the Point from the lake, the dominant currents being southward on both sides of the Point.

b) Although erosion occurred on the Point's east shore, the west shore was the recipient of sediment resulting in the westward migration of the Point.

Skafel (1975) attempted to assess the amount of beach sediment present and the direction in which it was transported along the Point. Skafel estimated a northward net transport on the west coast of 4000 cubic metres per year by drawing upon empirical relationships between wind velocity, fetch, wave height, wave period and sediment transport. In the same manner, he calculated an east coast net transfer rate of 26 000 cubic metres per year in a southern direction. Skafel hypothesized that the interaction of these two rates would reflect erosion on the east beach increasing in magnitude towards the tip.

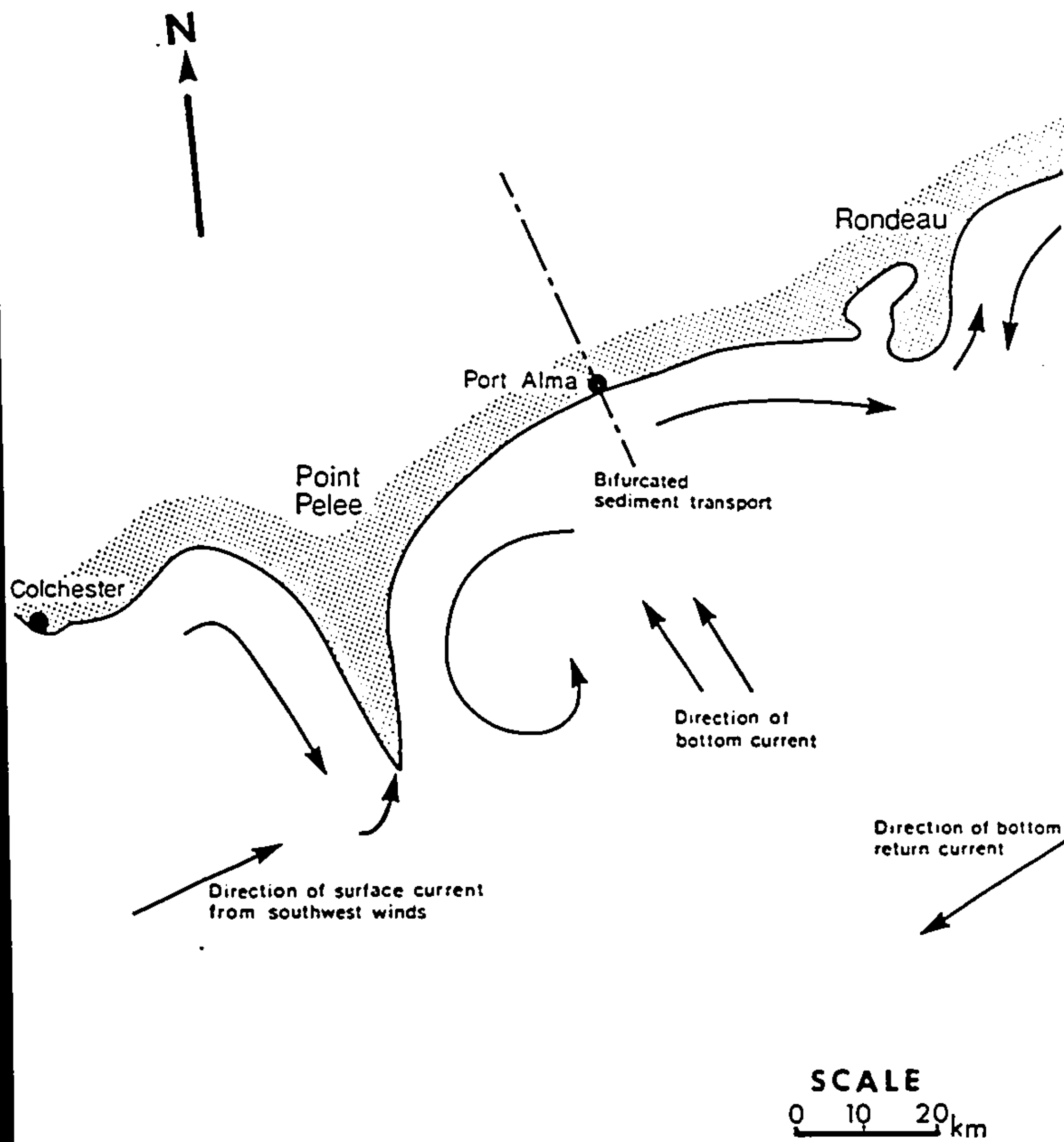
Coakley (1972), using grain size and heavy mineral analysis, indicated the existence of a general southward net transfer of sediments on both shores of the Point, possibly with a reversal in the southwest tip area under some conditions. The dominant sediment transfer pattern was inferred from the north to the south with some eastward influence. Although the results of Coakley (1972) and Skafel (1975) implied a dominant southern transfer, the former author indicated that it is unlikely that net eastern transfer plays a significant role. Coakley and Cho (1972) also noted that the littoral drift pattern in the Point Pelee area is variable, with predominant current directions on the western shore from the southeast to a reversal at the Point to the northwest. On the eastern shore currents were observed to flow predominantly north. The findings of Coakley and Cho (1972) contradicted those of Kindle (1933) by suggesting the existence of a more variable longshore drift condition than was previously observed. In 1972, Kamphuis studied littoral drift patterns on the east side of Point Pelee and noted that littoral drift was reversible in direction, averaging approximately 1900 cubic metres per year in a southern orientation. Bukata, Haras and Bruton (1975) have developed a schematic representation of currents responsible for littoral drift around Point Pelee (Figure 2). They suggested that the dominant sediment energy regime responsible for the geometry of Point Pelee lies between Port Alma to the east and Colchester to the west. Bukata, Haras and Bruton proposed a dominating western sediment transport pattern on the eastern shore of the Point.

Finally, Coakley (1980) noted that the main source of sediment contributing to littoral drift for the east side of Point Pelee was accepted as the eroding shore bluffs between Wheatley and Port Alma. Rukavina and St. Jacques (1976), stated that these bluffs supply approximately 50,000 cubic metres per year of sand material to the westward directed longshore transport. Southward directed rates of 25,000 cubic metres per year were obtained by Coakley (1980). It must be realized that only a portion of the estimated 50,000 cubic metres per year of the eroded bluffs reaches Point Pelee as shown by the severe shore erosion between Wheatley and the Point. It should also be noted that streams in the area contribute only negligible amounts of sand to the littoral drift process. East (1976) discovered that the major sources of sediment entering the littoral system are:

a) river, stream, and gulley erosion,

FIGURE 2

LAKE ERIE-BIFURCATING CURRENTS



Source: Bukata et al., 1975

b) erosion of offshore areas,

c) shoreline erosion.

In the Point Pelee region, East (1976) discovered that nearby streams contributed little if any to the littoral process. This was in direct contrast to Pethick (1984) who believed that ninety percent of all sediments were derived from rivers while erosion only contributes a small proportion of sediment.

The eastern side exhibited a net southerly sediment transfer movement. The area near the tip showed variable longshore movement with the existence of the shoal offshore as a temporary storage area for sediment.

On the eastern shoreline, overtopping of the berm by storm waves causing overwash of sand into the marsh and backbeach areas resulted in major sinks for littoral material. Coakley (1980) also acknowledged another sink for east side sediments found south of the tip, where the southward directed littoral system ends. Indications that part of the east side littoral drift is transferred across the low submerged spit and enters the northward littoral drift of the west side were also recognized. Thus, the east side of the tip area experienced erosion of approximately 0.4 metres per year while the west side accreted 0.3 metres per year (Coakley, 1980). Coakley (1978) also postulated a storage area near the tip from which sediments periodically re-enter the littoral drift system depending on the direction of the waves.

Coakley (1978) observed the interrelationships between lake processes and sedimentation at Point Pelee. He believed that the major agents of sediment transport were:

a) Surface waves and non-periodic changes in the surface elevation of the lake. Included in this phenomena are wave suspension and bottom drift of bed materials, longshore current generation and overtopping of the berm by washover. These tend to be especially evident on the east side, although they can be found throughout the entire nearshore zone.

b) Normal lake circulation. Seiches or net flow conditions generate stronger currents on the west side and shoal than the east side.

c) Intermittent dynamic phenomena. The turbidity levels associated with eddies and vortices are significant and need to be investigated.

Coakley further explained that variability in these phenomena are reflected in seasonal patterns. Most data concerning this topic has been collected for June, July, August and September. It is noted that the winds of the greatest magnitude and duration blow from the northwest and west during the summer.

Coakley postulated that the shoal and the west side of Point Pelee were the locations expected to show the most sediment transport. Since east or northeast storms were infrequent, the overall level of sediment resuspension and transport on the shoal was much lower in the summer than the spring. Further, on the east side, transport was expected to be low, with a slight net transport toward the north.

Sediment inputs through shore and bottom erosion would be low and both erosion and accretion were expected to occur along the shoreline.

Trenhaile and Dumala (1978) noted that sediment transport became increasingly important to the development of Point Pelee. They concluded that the shoal area immediately to the south of the Point is the result of the dynamic processes which formed this cuspate foreland instead of a relic feature of the original foreland as suggested by other authors.

2.3 SEDIMENT TRANSPORT STUDIES

Rathke *et al*. (1981) investigated settling fluxes in Lake Erie as measured by traps and settling chambers. The purpose of the investigation was to compare the detrital fluxes and sinking velocities as measured both by the sediment trap and settling chamber methods. Rathke *et al*., (1981) noted that there are various methods to measure the sinking velocities and settling fluxes of detrital particles, with the most common insitu method being the use of sediment traps, a technique reviewed by Bloesch and Burns (1980). Since exposure times of traps usually range from two to four weeks, the trap results provide information primarily on settling fluxes and accumulation rates. The focus of the analysis compared the settling fluxes and sinking velocities of particulate organic carbon measured by the sediment trap and settling chambers. The results of the particulate organic carbon analysis in conjunction with settling fluxes and sinking velocities found differences between these two experimental methods. Rathke et al., (1981) noted that chambers provide the advantage of the short time of exposure and the ability to measure settling flux and sinking velocity simultaneously. Traps, on the other hand, revealed mean settling fluxes over a two week period and thus reduced possible error in extrapolation. However, they were influenced by bottom resuspension, mineralization and colonizing animals. Rathke et al., (1981) also stated that the validity of the two techniques was established by Hargrave and Burns (1979) and Gardner (1977,1980).

Bloesch (1982) investigated onshore-offshore sedimentation differences resulting from resuspension in the eastern basin of Lake Erie. Cylindrical sediment traps were stationed onshore, midshore and offshore and retrieved at biweekly intervals. In addition, sediment cores were taken to test the hypotheses that:

a) Different sinking distances would influence the mineralization of plankton biomass and detritus.

b) Lake depth would affect settling fluxes caused by sediment resuspension resulting from water turbulence.

Thus, Bloesch (1982) considered the formation of bottom sediments as a dynamic process essentially governed by lake depth and wind induced currents. Chemical analysis of the empirical samples revealed significant onshore-offshore differences in chemical content.

Nummedal *et al.* (1984) considered sediment transport and morphology at the surf zone of Presque Isle, Lake Erie in Pennsylvania. Sediment transport calculations were analytically obtained with the use of hindcast annual wave power statistics calibrated by known accretion rates at the downdrift spit terminus. The sediment delivery rate was estimated from bluff retreat rates in the updrift while data on the downdrift accretion were derived from historical records of shoreline and bathymetric change as well as dredging records. Although sediment transport rates were utilized by Nummedal *et al.*, (1984), they were calculated analytically rather than measured empirically.

Lick and Kang (1987) analyzed entrainment and deposition of Lake Erie sediments. They examined net sediment flux as a process in which entrainment and deposition were independently considered. Net entrainment experiments were performed in which the net amount of material entrained was treated as a function of stress and time after deposition for three different sediments from the basin of Lake Erie. These sediments were fine grained and the cohesion of particles was significant. The authors implied that relatively little material was being resuspended. Deposition of sediments revealed that the decay time increased as the stress increased.

Erosion and sedimentation along the north-central shore of Lake Erie was investigated by Rukavina and Zeman (1987). They drew up a preliminary coastal sediment budget as a function of bluff erosion rates in conjunction with measurement of nearshore bottom types. In their recommendations, it is noted that sediment trap installation in the nearshore zone would be beneficial to measure the rates and directions of suspended sediment transport.

2.4 REVIEW OF LITERATURE PERTAINING TO PHYSICAL MECHANICS OF SEDIMENT TRANSPORT

In order to investigate this problem in detail, it is also necessary to understand the literature pertaining to the overall mechanisms and hydrodynamics of sedimentation. Only literature dealing specifically with the objectives outlined in this study will be reviewed.

Two major mechanisms contribute to total load sediment transport, namely bedload and suspended load transport. Bedload grains are supported mainly by grain to grain forces, while suspended load consists of moving grains supported by primarily the surrounding fluid (Nielson, 1984). The nature of this investigation concerns itself with suspended sediments rather than bedload. Sediment on the bed of a limnetic environment will not begin to move unless the flow acting on the particles surpasses a certain critical value. Alternately, for a given flow, there will be some maximum size of sediment that the flow can move

(Blatt, et al., 1980). The initiation of particle movement is accepted as the Shields solution for the simplified case of a plane bed composed of sediment of uniform grain size (Figure 3). The beginning of movement of particles on the bed will be related to the size of the particle d, its submerged specific weight $(\gamma_s - \gamma)$, the shear stress acting on the bottom, τ_0, the viscosity, μ, and the density ρ, of the fluid according to the formula used by Blatt et al., (1980) : $f[d, (\gamma_s - \gamma), \tau_0, \mu, \rho] = 0$

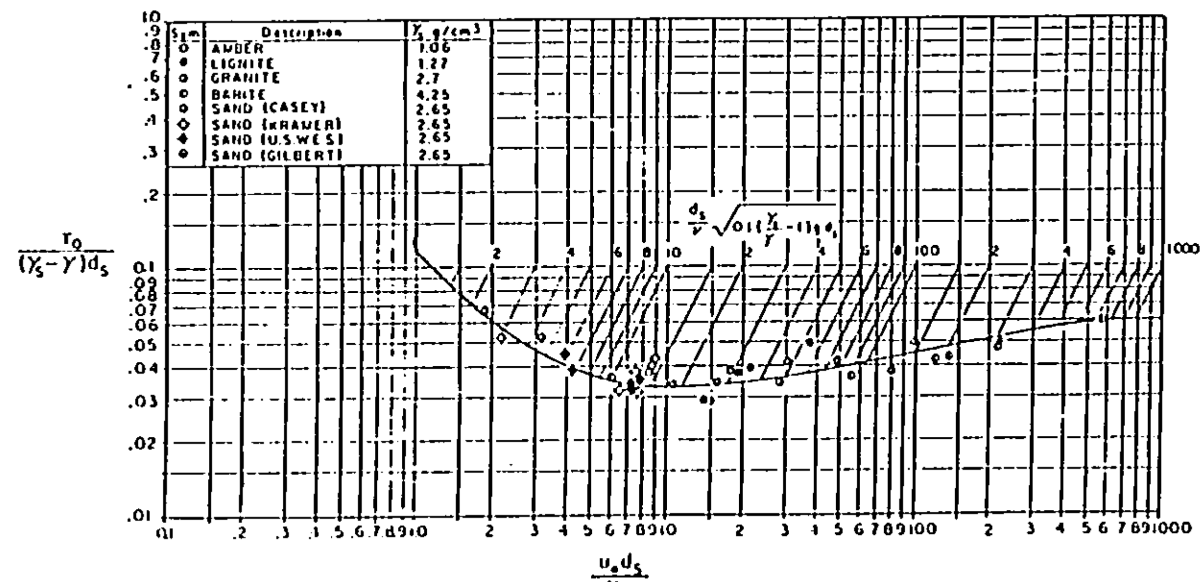
From the Shields diagram, it is known that movement begins over a range of conditions rather that at a well defined flow criterion.

In 1966, Jonsson devised a wave friction factor which enables the determination of the magnitude of the maximum bottom shear stress associated with oscillatory fluid motion. The Shields Criterion obtained for unidirectional steady flow is applicable as a general criterion for the onset of sediment movement in oscillatory unsteady flow. It is assumed that the Shields Criterion represents the critical value of the ratio of entraining to stabilizing forces acting on a sediment grain in the sediment-fluid interface (Madsen and Grant, 1976).

Einstein (1950) suggested similarity between the sediment transports in unidirectional flow and the oscillatory flow. For a unidirectional steady flow the

FIGURE 3

SHIELDS' DIAGRAM



Shields' diagram, as modified by Vanoni (1964, Caltech W. M. Keck Lab. Hydraulics Rept. KH-R-1). To calculate shear-stress required to move a given sediments, calculate $(d/\nu)\sqrt{0.1[(\gamma_s/\gamma) - 1]gd}$, locate this value on the scale given in the center of the diagram, find the intersection of the Shields curve with the projection of this value along the diagonal lines on the diagram and read off the value of β on the ordinate.

Source: Vanoni, 1964

sediment will be transported in the direction of flow. Sediment transport rates are determined by establishing a relationship between fluid and sediment properties as well as flow characteristics and the rate at which sediment is transported (Madsen and Grant, 1976). In a marine environment, the introduction of oscillatory flows and turbulence complicates sediment transport. Oscillatory unsteady flow may be found in the to-and-fro motion of the near-bottom fluid particles under waves. Several empirical criteria for the onset of sediment movement under this flow pattern have been advanced. Bagnold (1946) and Vincent (1958) both related the amplitude of the nearbed fluid particle motion relative to the bed and the period of oscillation corresponding to the critical condition of initiation of sediment movement. The authors generated a set of curves which correspond to particular sediment characteristics. Madsen and Grant (1976) noted that relationships of this kind are usually limited by the range of experimental conditions from which they were derived and are not of the nature of the Shields Criterion for unidirectional steady flow.

Horikawa and Watanabe (1967) and Kajiura (1968) suggested more general criteria for the initiation of sediment movement under waves. Madsen and Grant (1976) observed that the above mentioned authors evaluated the stability of a single grain on the sediment - fluid interface based on the concept of the maximum bottom shear stress associated with oscillatory flow.

Kana (1978) and Kennedy and Locher (1972) noted that it is generally recognized from laboratory studies in oscillatory flow that suspended sediment concentration decreases exponentially as distance from the bed increases. It is also noted that in 1969, Hattori studied the vertical and horizontal distributions of mean sediment concentration under a standing wave. He introduced the notion of a "delay distance" to account for particle inertia. Kennedy and Locher (1972) utilized Hattori's concept of "delay time" to propose analytical models for sediment suspension. Their results produced a model which generates accurate measurements of mean concentration distribution of sediments in a wave field.

Skafel and Krishnappan (1984) extended the work of Kennedy and Locher by attempting to derive a model to predict suspended sediment concentration due to wave agitation. They utilized the diffusional approach to construct a model which predicted certain aspects of sediment concentration and distribution. Larsen _et al._, (1981) continued research into empirical verification of predictions of the threshold of grain motion under oscillatory flow conditions. They concluded that the Shields entrainment function for unidirectional flow could be used to predict the threshold of grain motion for oscillatory flow conditions. The Shields diagram was plotted as a function of the grain Reynolds number and found to adequately predict the initiation of grain transport.

Staub (1984) investigated the notion of suspended sediment concentrations utilizing a syphon to generate these sediment concentrations and to tabulate the Shields parameter. He attempted to provide measurements of the time variation of sediment concentrations above a sandy bed under sheet flow or high shear conditions. A syphon probe was used to suck out a sand and water mixture from a fixed point to generate sediment concentrations. The results indicated that this type of sampler was suited for measuring instantaneous sediment concentrations in oscillatory flows despite calibration drawbacks (Blatt et al., 1980).

Dally and Dean (1984) reviewed the literature and developed a list of criteria that a "good" beach profile model should satisfy. From this, they proceeded to develop a model which included four of their five criteria. The model appeared to:

a) generate profiles of either the normal or storm types, depending on wave conditions and sediment characteristics.

b) predict the proper shape of the profiles.

c) respond to changes in water levels.

d) draw the relative rates of profile evolution correctly.

Yet, the ultimate conclusion put forth by Dally and Dean was that more research is required before quantitative accuracy can be achieved.

Vongvisessomjai (1986) considered sediment suspensions from mobile sand beds caused by progressive waves on water of constant depths whose vertical variations of sediment concentrations were pronounced while horizontal variations were small. He concluded that a diffusion coefficient profile adapted from the eddy viscosity profile was found to be suitable in describing the profile of mean concentration.

Bowen and Doering (1984) noted that in terms of sediment transport there was general agreement that incident waves are primarily responsible for the mobilization of sediment. However, many processes have been proposed as transport agents; for example, wave drift velocities, wave asymmetry, longshore and rip currents, undertow and the downslope component of gravity. It is this uncertain combination of energy inputs into the nearshore environment coupled with sediment characteristics which determine when and how long sediment will be in suspension.

vanRijn (1986) attempted to develop a two dimensional vertical mathematical model for suspended sediment transport by currents and waves. He defined a complex set of sediment transport processes including:

a) The convection of particles by horizontal and vertical fluid velocities,

b) the diffusion of particles due to current related and wind related mixing processes,

c) settling of particles due to gravity,

d) the picking up of particles from the bed by the flow.

The convection diffusion equation is:

$$\frac{\partial}{\partial x}(buc) + \frac{\partial}{\partial z}\left[b(\omega - \omega_s)c\right] - \frac{\partial}{\partial z}\left(b\epsilon_{s,cw}\frac{\partial c}{\partial z}\right) = 0$$

where u = longitudinal velocity at height z above the bed,

c = sediment concentration,

w = vertical flow velocity,

ω_s = particle fall velocity of suspended sediment,

$\epsilon_{s,w}$ = sediment mixing coefficient by current and waves,

b = flow width,

x = longitudinal coordinate,

z = vertical coordinate

The characteristic parameters of the mixing coefficient were related to general wave parameters yielding:

$$\epsilon_{s,w,bed} = \alpha_1 \delta \hat{u}_{b,w} \qquad \epsilon_{s,w,max} = \alpha_2 \frac{h H_s}{T_s}$$

where, H_s = significant wave height,

T_s = significant wave period

α_1 = coefficient,

α_2 = coefficient,

δ = thickness of the nearbed mixing layer,

$\hat{u}$ = peak value of orbital velocity at bed according to linear wave theory,

b= wave related mixing coefficient close to the bed,

w= wave related mixing coefficient in the upper half of the water depth.

The variety of parameters considered indicates the complexity of forces responsible for suspended sediment transport. vanRijn (1986) found agreeable similarity between computed and measured sediment concentration profiles. Accurate boundary condition information is found to be of considerable importance in this particular model.

Despite extensive research on sediment transport mechanisms, Nielsen (1984) determined that it is not possible today to derive a detailed theory for suspended load transport from basic physical principles. This necessitates the collection of empirical data from a variety of conditions to better explain this phenomena.

Inman et al., (1980) measured forcing functions(wind, waves, currents) in and outside of the surf zone as well as sediment response in terms of bed and suspended load movement. He found that a comprehensive model of longshore transport as well as on-offshore transport will need to incorporate suspended load as a fundamental component of total load.

Fairchild (1984) conducted a suspended sediment study and showed that there is a large variation in suspended sediment concentration, but the concentrations do depend on the elevation above bottom, wave height and position in the surf zone.

Sternberg et al., (1984) investigated sediment transport to reveal concentration profiles of suspended sediment, the average suspended sediment loads and the longshore particle flux in relation to varying wave conditions. Results indicated that sediment transport occurs as individual suspension events related to incident wave motions and infragravity motion oscillations within the surf zone; suspended sediment concentration decreases approximately logarithmically away from the sea bed; the maximum value of longshore transport rates occur in the mid surf zone; and the measured suspended sediment longshore transport rate is equal to the total longshore transport rate as predicted by existing transport equations.

Katoh et al., (1984) measured the concentration of suspended load and the current velocity in the surf zone. The authors found that the mean concentration of the suspended load was high in the final breaking zone. As well, the directions of the net transport of the suspended load in the middle layer in and near the surf zone are offshore.

Justensen et al., (1986) hypothesized that the vertical distribution of suspended sediment in the surf zone is of major importance for the evaluation of the rate of longshore as well as the on-offshore sediment transport. Outside the point of breaking, the presence of suspended sediment is restricted to the thin wave boundary layer. Models to describe this have been developed by Bakker (1974), Grant and Glenn (1983) and Fredsoe *et al.*, (1985).

2.5 A PRIORI MODEL

Based on the findings of the literature, and given the objectives of the study, an a priori model can be developed (Figure 4). The nearshore zone must be treated as an open system which may or may not be in a state of dynamic equilibrium with coastal processes. These processes include wind, waves and currents which bring in and remove sediment from a beach site. Development of a response model for the nearshore zone will illustrate the relationships between the inputs of energy, the sediment transport processes and the output of distinct sediment suspension characteristics for a particular site in the nearshore zone. The energy input into the nearshore system will be from wind, which generates waves, and currents. This energy, in conjunction with beach material and material carried in the water, will combine with the primary sediment transport processes. According to vanRijn (1986), the most relevant of these processes which can be considered are:

a) The convection of the particles by horizontal and vertical fluid velocities.

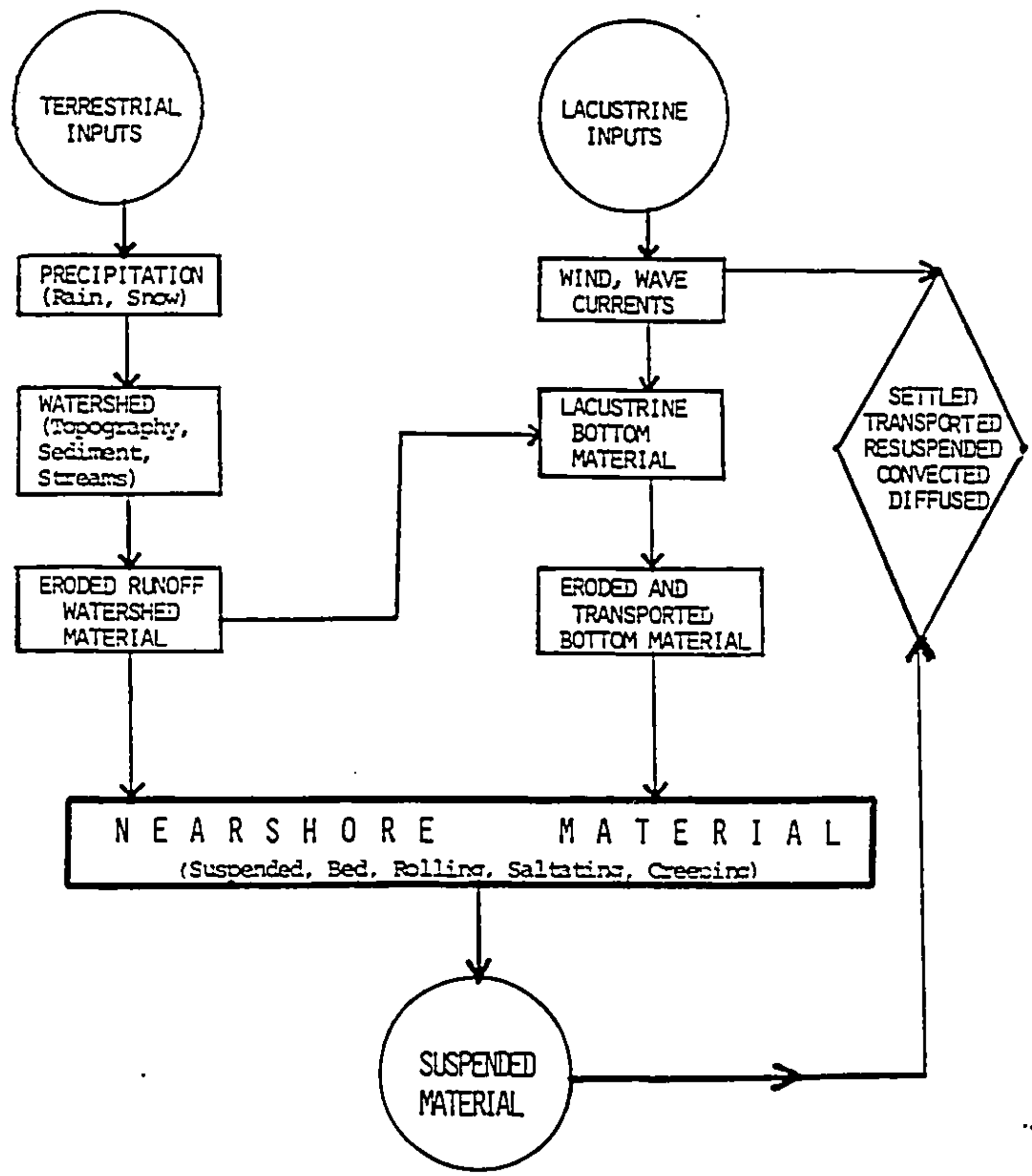
b) The diffusion or mixing of the particles due to current related and wave related mixing processes.

c) The settling of particles due to gravity.

d) The lifting of particles from the bed by the flow.

FIGURE 4

A PRIORI MODEL OF NEARSHORE SUSPENSION DYNAMICS



Source: V.C. LAKHAN (1987)

The output of this system will result in distinct nearshore sedimentary forms at a particular site. Feedback to the system stems from either the settling of particles to contribute to additional beach material or the resuspension of sediment to contribute to littoral drift.

2.6 HYPOTHESES

Very little research has been done on the collection of sediment with the use of sediment traps over different depths in the nearshore zone. The absence of any data on this topic justifies the depth differentiation in this investigation. Although other investigators have utilized sediment traps to adequately represent sediment masses in the nearshore zone in other regions, they have been primarily restricted to organic analysis of the collected sample rather than the rates of accumulation in the nearshore zone. As well, no one has attempted to perform this type of investigation in the nearshore zone of Point Pelee.

Based on the reviewed literature, the objectives of this thesis, and the a priori model, it is hypothesized that:

1. Water depth influences the mass of sediment collected in the nearshore zone.
2. Sediment accumulation rates reflect temporal variations in the nearshore wave environment.

CHAPTER 3

3.0 METHODOLOGY

3.1 REMARKS ON SEDIMENT TRAP DESIGN

Since this study involves an analysis of suspended sediment accumulation rates over time, it necessitates the design and installation of a series of sediment traps. When implemented and used correctly, a properly designed trap will measure the downward flux of particles in the limnetic environment surrounding the trap. A trap positioned in water containing particles which had settled from above and resuspended from below would measure the total downward flux of particles in the surrounding water (Hargrave and Burns,1979). Bloesch and Burns (1980) empirically validated the use of cylindrical traps with high aspect ratios, where the aspect ratio refers to the ratio of the length of the cylinder to its diameter. Cylinders with aspect ratios of ten or greater collected ninety five to one hundred percent of the particulate matter present. In addition, with an adequate flow across the mouth of a trap, the resulting fluid exchange will maintain the concentration of particles within the trap, with fall velocities typical of those outside, despite loss through sedimentation. As well, the higher the aspect ratio, the less the chance that horizontal flow will induce turbulence at the bottom of a settling chamber (Hargrave and Burns,1979).

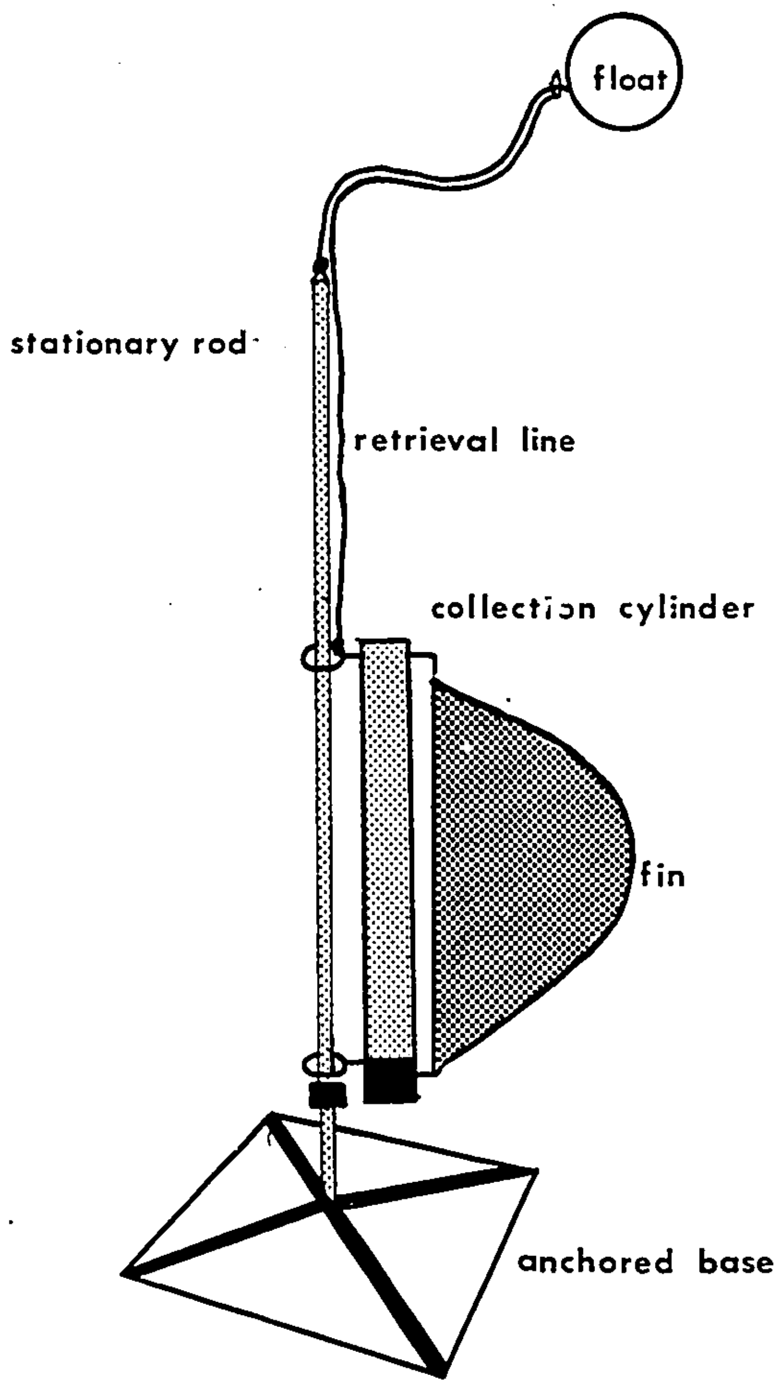
Hawley(1988) states that the two primary criteria for trap design are: a consistent concentration of particles both inside and outside of the trap; and that there should be a region of tranquil water at the bottom of the trap. He further notes that previous work has recommended an aspect ratio of 10 was appropriate for Lake Erie.

3.2 SEDIMENT TRAP DESIGN AND IMPLEMENTATION

Five cylindrical sediment traps based on a modified design from Hargrave and Burns (1979) were utilized for this investigation (Figure 5). Each apparatus consists of a weighted base with a rod extending perpendicular to the base. The cylinder itself is attached to this rod and is able to be slid up and down for retrieval purposes. The cylinder is supported by a cup at the bottom in addition to a ring to supporting the upper portion. The supports for the cylinder are attached to the rod on one side and a fin 180 degrees to the cylinder on the other side. This fin enables the trap to orient itself with the current. If the trap is stationary, it is postulated that vibration from passing currents would exert sufficient energy to agitate the settled contents of the sediment trap. Knowing the bathymetry of the Point Pelee area (Figure 6) and sediment movement patterns around the Point (Figure 7) the traps were placed at various depths around the vicinity of the tip to

FIGURE 5

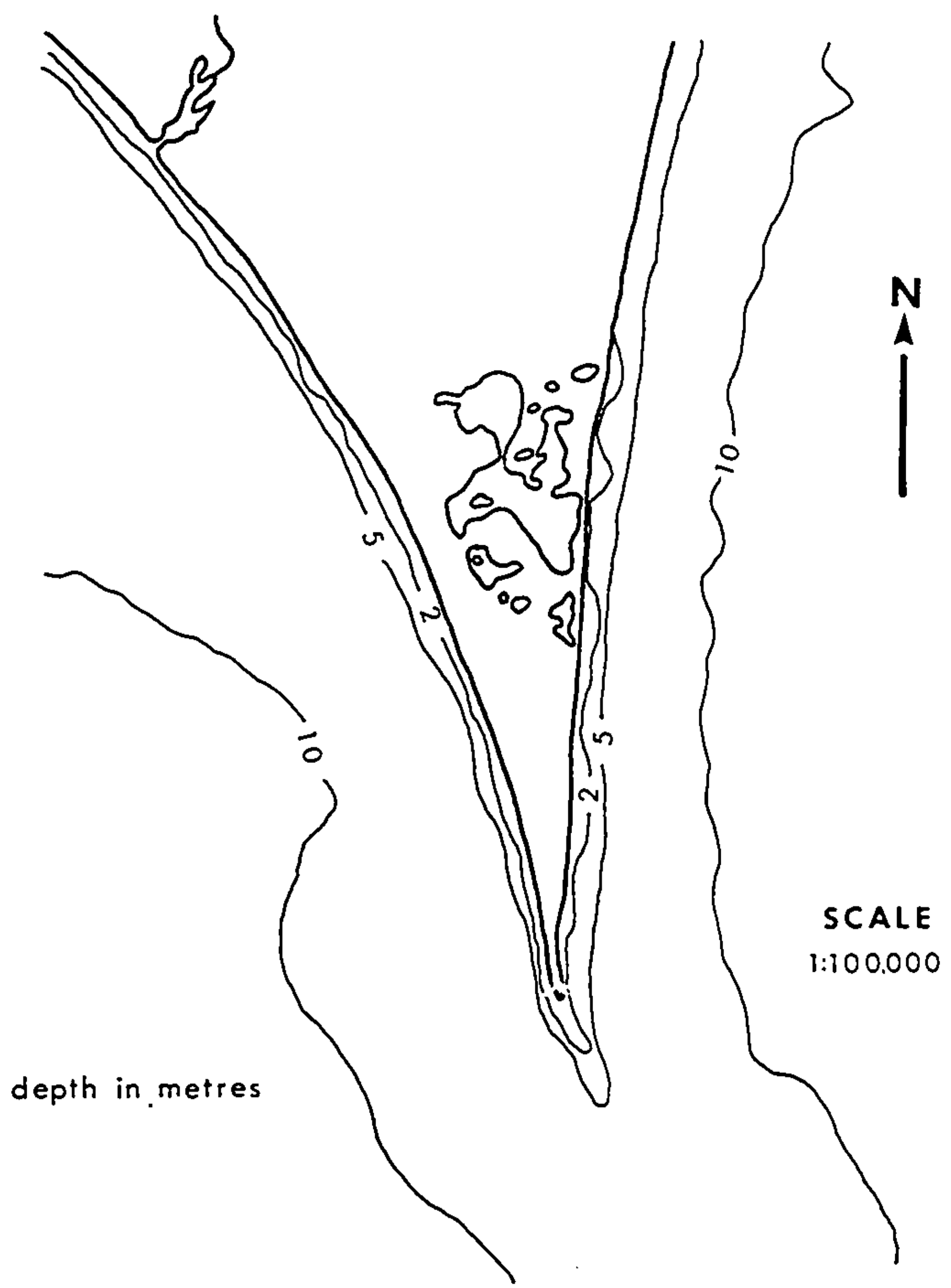
SEDIMENT TRAP APPARATUS



Source: after Hargrave and Burns, 1979

FIGURE 6

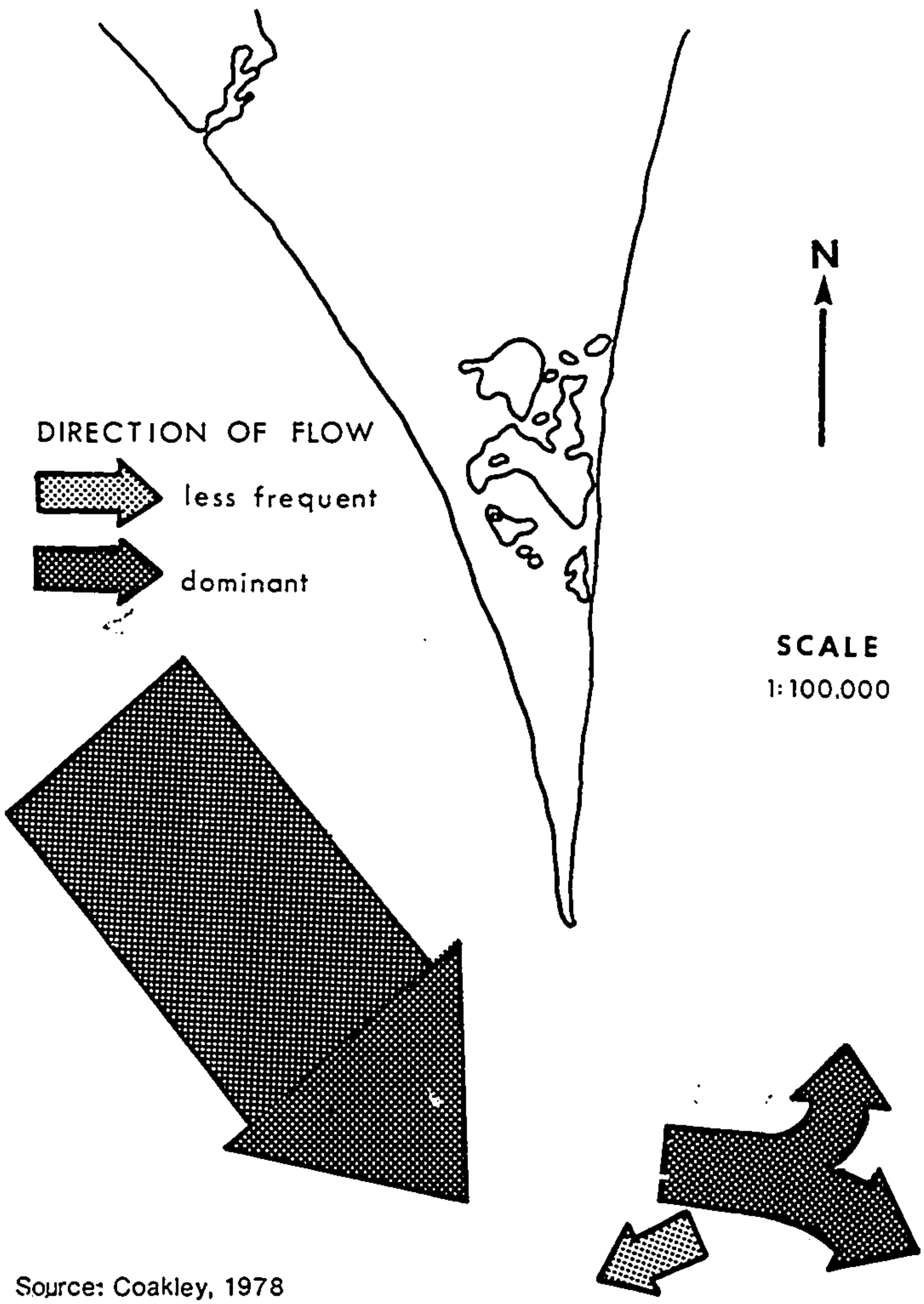
BATHYMETRY OF POINT PELEE



Source: Min. of Fisheries and Oceans, 1987

FIGURE 7

POINT PELEE SEDIMENT PATTERNS



Source: Coakley, 1978

account for nearshore variation in sediment flux over space, over time and at different depths of water. Each catchment apparatus was stationed in the nearshore zone at the tip of Point Pelee. Traps were placed at the following depths: 10 feet(3.05m)for trap 1; 15 feet(4.57m) for trap 2; 25 feet(7.62m) for trap 3; 6 feet(1.83m) for trap 4; 12 feet(3.66m) for trap 5. (Figure 9).

According to Coakley (1978), during the summer months, the west side of Point Pelee is expected to show the most sediment transport. On the east side, transport is expected to be lower, with a slight net transport toward the north. Thus, traps 3, 4 and 5 were placed on the east side and traps 1 and 2 were placed on the western side of Point Pelee (see Figure 8).

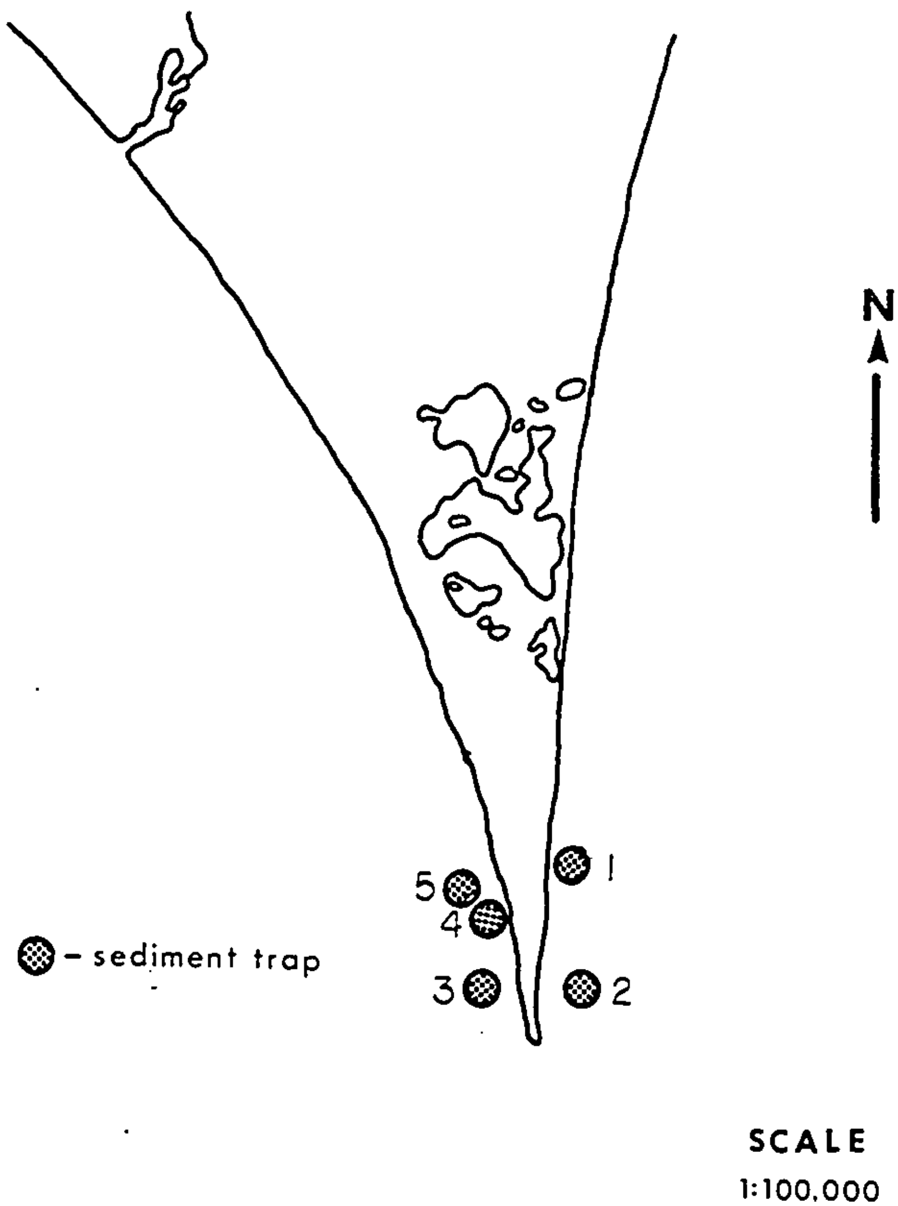
The problem of mineralization of organic matter in sediment traps probably will never be resolved, because it is a natural biodegradation process, but the amount of mineralization can definitely be minimized by using short exposure periods (Bloesch and Burns,1980). Thus, it is postulated that a two week sampling period will be adequate to discover sediment accumulation rates yet prevent mineralization in the sediment trap.

3.3 DATA COLLECTION PROBLEMS

As with any field work, this research was not without its on site aberrations. Weather conditions were the

FIGURE 8

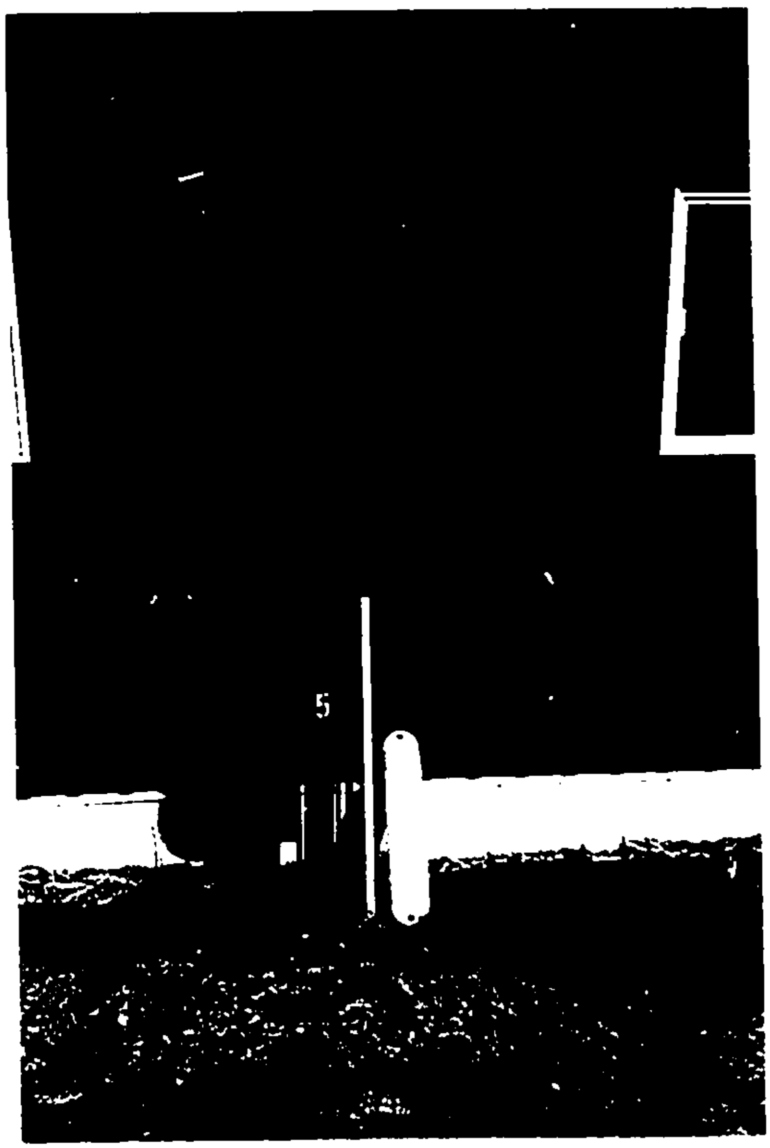
LOCATION OF SEDIMENT TRAPS



Source: Libby fieldwork-June 22,1988

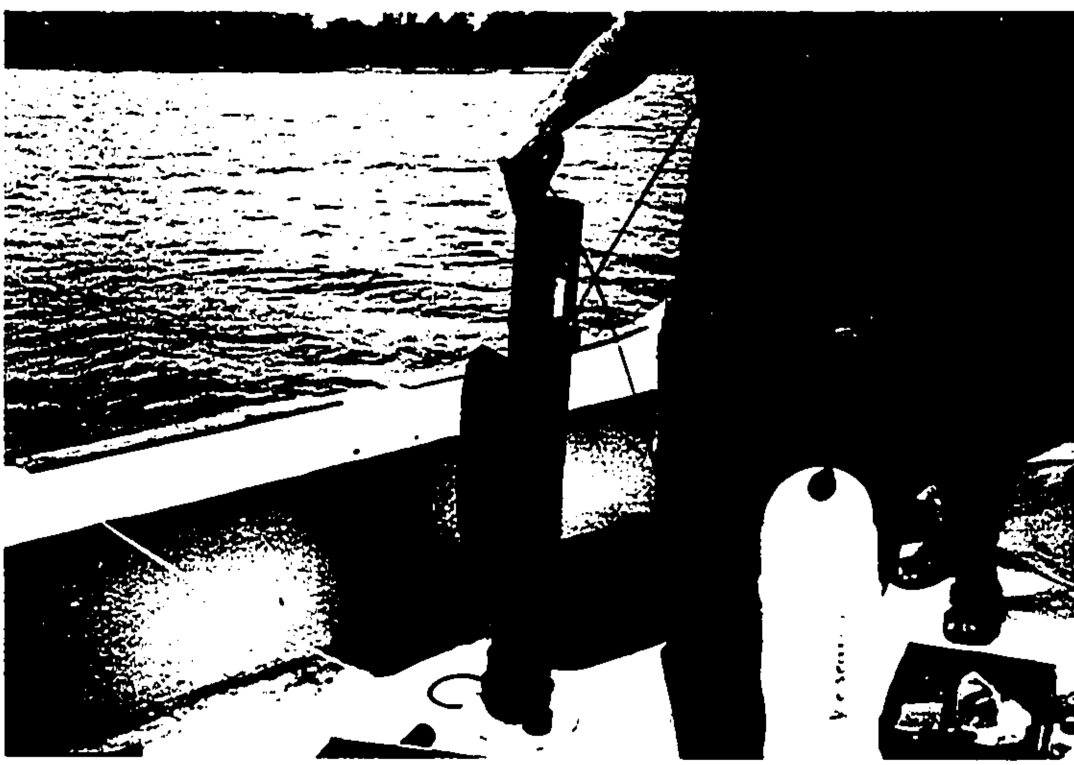
FIGURE 9a

INSTALLATION OF SEDIMENT TRAPS



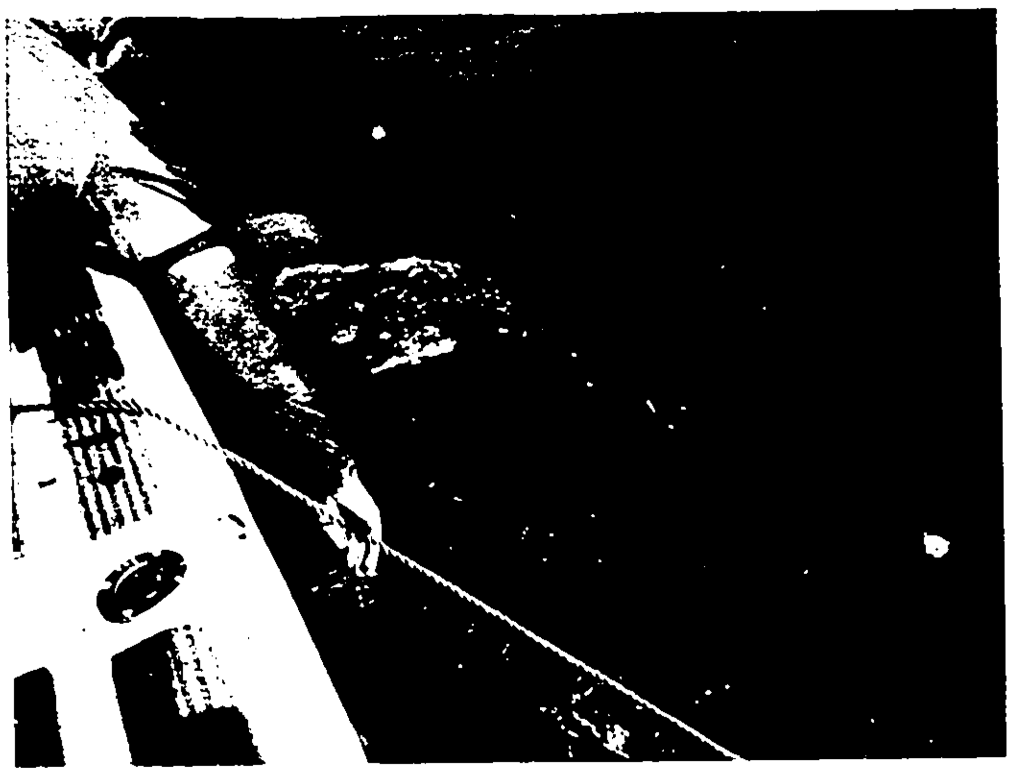
Source: Fieldwork, 1988

FIGURE 9b



Source: Fieldwork, 1988

FIGURE 9c



Source: Fieldwork,1988

FIGURE 9d

Source: Fieldwork, 1988

FIGURE 9e

Source: Fieldwork,1988

FIGURE 9f

Source: Fieldwork, 1988

primary delay when attempting to retrieve sediment samples. Consequently, samples were collected on July 5, July 20, August 3, August 17, August 30, September 15, and September 29 of 1988. The collection period intervals range from 13 to 15 days in length.

In addition to weather induced alteration of the collection period intervals, human curiosity and carelessness also contributed to the variability of this investigation. On August 3, the traps were inspected by a scuba diver and three had to be reinstalled because of missing buoys or damage to the equipment itself. Trap 3 vanished by September 29 for reasons unknown to the investigator. Fortunately, four consecutive samples were obtained before its disappearance.

3.4 METHOD OF RETRIEVAL

A small boat was used to access each station to retrieve the bi-weekly sediment samples. Each of the cylinders were drawn to the surface by hand and immediately capped to prevent spillage. They were taken to the Department of Geography Soils Laboratory at the University of Windsor and allowed to settle for one week prior to decanting off the excess water. The remaining sediment-water mixture was transferred to metallic pans and then placed in a Gallenkamp convection oven to dry. Once the samples were dried, the sediment was carefully brushed into plastic bags which were then sealed and labelled appropriately.

3.5 LABORATORY ANALYSES

To account for spatial variation among individual sediment traps, the analytical approach was the next stage of the methodology. The results of each sediment sample when evaluated in terms of weights and particle size distributions, will yield information on spatial variability among each sample site. The first step was the determination of the total mass of the dried sample collected from each individual cylinder. This was recorded using an analytic balance. After confirming and recording the mass of the samples, hydrometric analysis was executed on each sample for every sampling period to determine the proportion of grain sizes present per measured volume of water in each cylinder. The procedures for this technique are well documented by the American Society for Testing and Materials (ASTM,1963). The standard method for grain size analysis of soils covers the quantitative determination of the distribution of particle sizes in soils. By observation, the sediment samples were too fine grained to sieve. As a result, hydrometric analysis was utilized to determine particle size.

3.6 COMPUTER MODELS

In order to account for the temporal variation of sediment over time, some type of relationship must be developed between sediment collection periods and corresponding nearshore conditions so that it may be observed whether there is a link between the environment and amount of sediment collected.

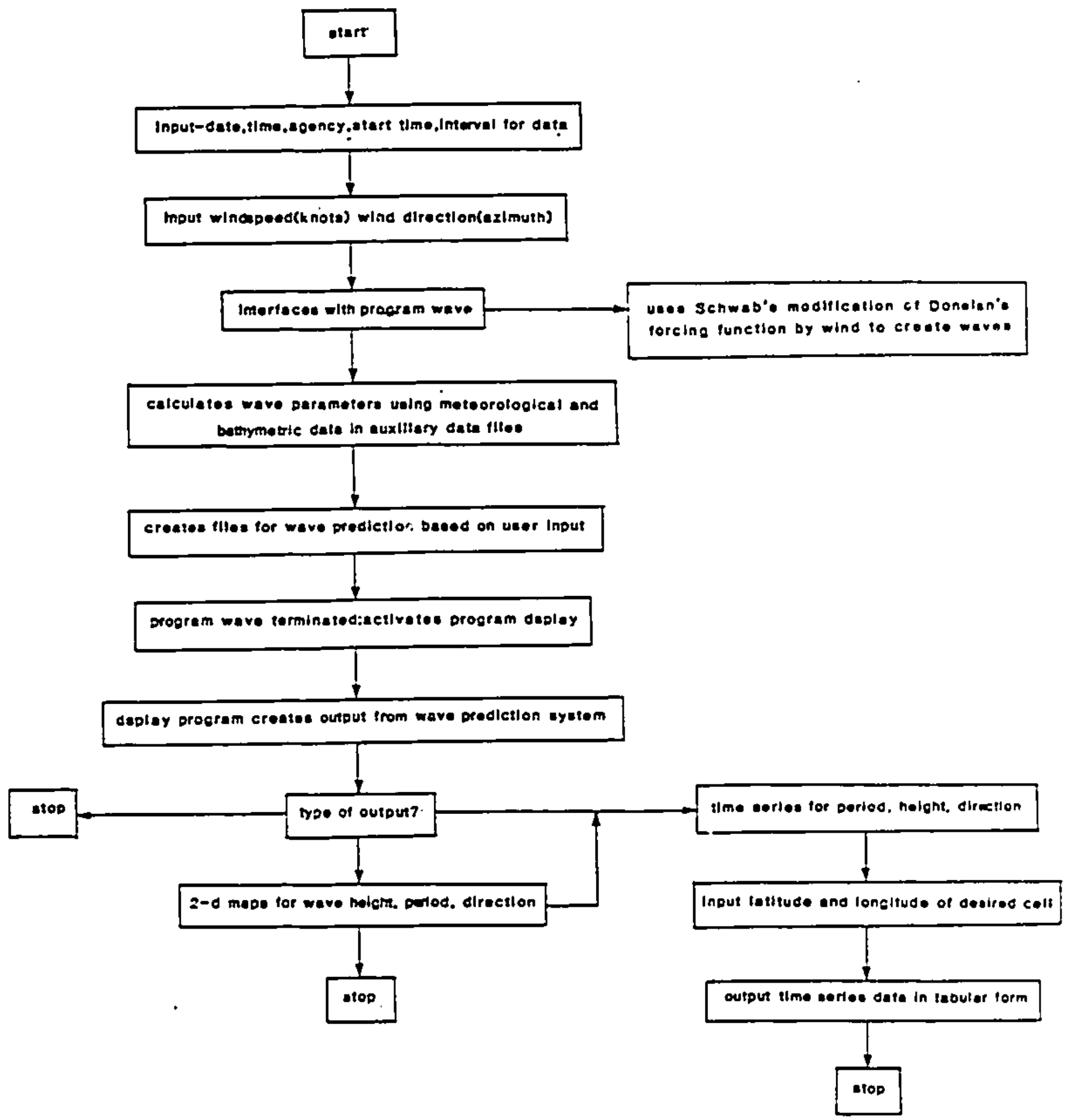
Bishop and Donelan (1985) note that the driving force behind almost every coastal process is waves. They acknowledge that the wind is responsible for producing waves in the limnetic environment. Komar (1983) observes that two of the most important factors in the generation of wind waves are wind speed and wind duration. Hourly wind data is available for Point Pelee from Parks Canada in the form of wind direction (letter orientation i.e. N,S,E,W) and wind speed (miles per hour). These two indicators can be used to determine wave height, wave direction and wave period for Point Pelee. Consequently, wind direction and speed was obtained for July, August, September and October of 1988 from Parks Canada. This wind data (Appendix A) was recorded at a station positioned 10 metres above the surface in order to reduce the effects of surface drag or friction upon the actual wind speed.

Before the raw wind data can be utilized, it must be converted to knots and to direction in degrees. This was possible with the use of Windcon (Appendix B). This program converts wind direction from letters to angle values and wind speed from miles to knots.

Once the raw data for July, August, and September have been converted, this output now becomes the input for a second program, "A Two-Dimensional Lake Wave Prediction System" (Schwab et al.,1984) which displays the wave height, direction and period as two dimensional fields. As well, the time series of wave height, direction and period at a given location can also be calculated. Schwab et al., (1984) has developed this numerical model based on the work of Donelan (as presented by Bishop 1983) which has been modified to conform to the Great Lakes Environmental Research Laboratory two dimensional lake circulation system. This model was tested by Schwab et al., (1984) and Liu et al., (1984) and found to perform successfully when predicting wave heights in the Great Lakes. However, it is also noted that this particular model also tends to underpredict when applied to shoreline regions. Kovacs (1987) and Namikas (1988) both utilized this prediction system to calculate wave direction, height and period for Lake Erie when conducting investigations on beach-current relationships at Point Pelee. Reference is made to Schwab et al.,(1984) for complete documentation of this program. Figure 10 is a schematic of the process model associated with the prediction system.

FIGURE 10

PROCESS MODEL FOR TWO-DIMENSIONAL LAKE WAVE PREDICTION SYSTEM



SOURCE: Schwab, 1984

3.7 STATISTICAL ANALYSES

The collected data will be summarized in tabular form to illustrate the dried weights of the sediment samples. In addition, average amounts of sediment collected at each site for a single depth and over time for all depths will be portrayed. Average wave height and wave period obtained from "A Two-Dimensional Lake Wave Prediction System" program will be compared to the average amount of sediment collected for each sample interval. Once initial relationships are drawn, they will be tested to reveal the presence or absence of statistical significance between them. One way analysis of variance (ANOVA) will test for variability accounted for by a) both time and depth (site) differentiation,

b) time alone,

c) site alone.

CHAPTER 4

4.0 OBSERVATIONS AND ANALYTICAL FINDINGS

4.1 SUMMARY OF COLLECTED DATA

The amount of sediment (in grams) retained in each trap over the entire sampling period is illustrated in Table 1.

TABLE 1

SEDIMENT MASSES FOR JULY 5 TO SEPTEMBER 29 (grams)

SITE	DATE OF RETRIEVAL						
	July5	July20	Aug3	Aug17	Aug30	Sept15	Sept29
1	25.3704	1.8911	1.2943	21.042	28.0988	15.4281	48.7012
2	-----	-----	-----	1.3143	10.2344	7.2388	21.9418
3	3.2451	6.4727	3.3819	17.4986	31.5930	-----	-----
4	8.3173	8.1247	5.9920	48.7081	81.4569	45.6971	-----
5	7.2276	9.5587	4.0490	19.0439	32.6107	18.0219	115.5672

The blanks correspond to periods of collection in which the sediment traps were missing or unretrievable due to mechanical failure. Thus, only sites 1 and 5 remained completely operational for the duration of the sampling period. It was impossible to collect data from site 2 until a scuba diver reinstalled it prior to August 17. Site 3 was unserviceable after August 30. Site 4 was unretrievable by September 29.

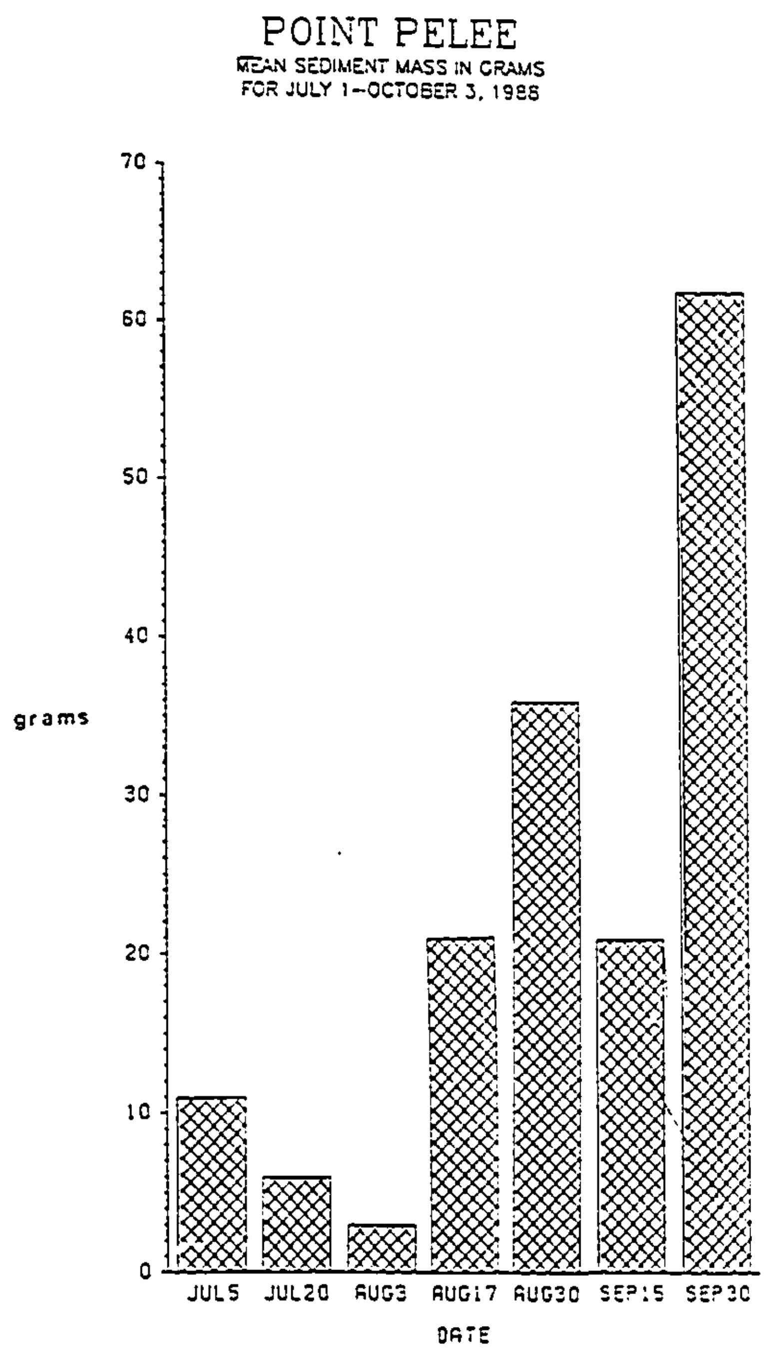
From the raw data, the mean values are calculated for each sampling period and are displayed in Figure 11. Missing data were accounted for by including only those sites for which samples were collected in the calculation of the averages.

The first three periods illustrate significantly less amounts of sediment collected. July 5 sample shows a mean of 11.0401 grams, July 20 sample with a mean of 6.5118 grams, and August 3 sample with a mean of 3.6793 grams. August 17,30, and September 15,29 samples collected more sediment with averages of 21.5214 grams, 36.7988 grams, 21.5965 grams and 62.0701 grams, respectively.

Variation in amount of sediment caught is expected because the nearshore zone conditions do not remain static. The first three sampling periods occur in mid summer when conditions on the Lake are relatively calm. Winds are of a low velocity which is reflected in lower wave heights. During the summer months, the winds of the greatest magnitude and duration blow from the northwest and west (Coakley,1978). As September and October approaches, the strength of the winds increase with the approaching storm season. One expects the increase in energy to be responsible for the collection of increasing amounts of sediment.

Sites 1 to 5 demonstrate the initial variation of this investigation over depth (Table 2). Each site represents a different depth with site 1 at 10 feet(3.05m), site 2 at 15

FIGURE 11



SOURCE: FIELDWORK, 1988

feet(4.57m), site 3 at 25 feet(7.62m), site 4 at 6 feet(1.83m) and site 5 at a depth of 12 feet(3.66m).

TABLE 2

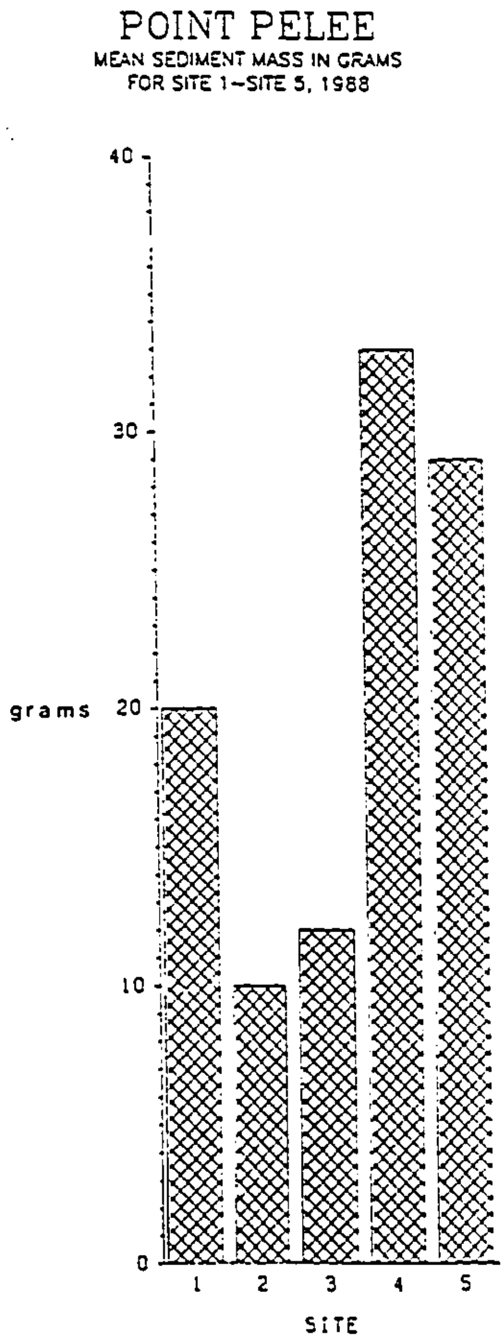
DEPTH CLASSIFICATION OF SEDIMENT TRAPS

Site	Position in the nearshore zone		
	shallow	intermediate	deep
1 (3.05m)	X		
2 (4.57m)		X	
3 (7.62m)			X
4 (1.83m)	X		
5 (3.66m)		X	

Sites 1 and 4 may be classified as shallow locations; sites 2 and 5 are intermediate locations while site 3 is considered a deep region. Sites 1, 2 and 3 are installed in the eastern nearshore zone while sites 4 and 5 are located in the western nearshore zone of Point Pelee. Figure 12 portrays the average amount of sediment collected at each site over the entire sampling period. This histogram lends itself to preliminary spatial assessment of the effect of varying depth on the amount of sediment collected.

Site 1 collected an average of 20.2608 grams over the entire collection period. Site 2 collected 10.1823 grams, site 3 with 12.4383 grams, site 4 with 33.0494 grams and site 5 with 29.4399 grams, on average. The average amount of sediment for sites 1,4,and 5 is 27.5833 grams while the deeper sites were responsible for an average of 11.3103 grams of sediment.

FIGURE 12



SOURCE: FIELDWORK, 1988

Through observation, there is an initial relationship between depth of the sediment traps and sediment mass. The traps located in shallower water are responsible for retaining more sediment, on average, than the traps located in deeper waters. This is an obvious expectation since the shallower the water, the more energy transferred due to breaking waves and the more sediment that is suspended. As the amount of suspended sediment increases, the amount of sediment caught by the trap also increases. This is directly reflected in the comparison of the depth that the trap is installed to the amount of sediment that it is responsible for.

4.12 PARTICLE SIZE DISTRIBUTIONS

The results of the hydrometric analysis reveal that the traps, although they are responsible for retaining a small amount of fine sand, predominantly retained silt and clay sized particles. The contents of the traps fall within the following classifications:

TABLE 3

PARTICLE SIZE CLASSIFICATION

Type	o unit	mm Wentworth scale
fine sand	2.0 to 3.0	0.25 to 0.125
very fine sand	3.0 to 4.0	0.125 to 0.0625
coarse silt	4.0 to 5.0	0.0625 to 0.0312
medium silt	5.0 to 6.0	0.0312 to 0.0156
fine silt	6.0 to 7.0	0.0156 to 0.0078
very fine silt	7.0 to 8.0	0.0078 to 0.0039
coarse clay	8.0 to 9.0	0.0039 to 0.00195
medium clay	9.0 to 10.0	0.00195 to 0.00098

Source: King, 1966

The results are expected because of the calm conditions during the summer of 1988. The general quiescence experienced during that summer with respect to storms and strong winds is reflected in the absence of any larger sized particles in the sediment traps. Another suggestion for this may be because the bedload in the vicinity of the sediment traps was not monitored. Further investigation in this area should consider bedload as one of the variables to be examined.

In the absence of bedload information, the collection of small diameter particles is attributed to calm weather conditions. Since the process of sediment suspension requires the presence of an adequate amount of energy, the calm conditions experienced throughout the study period (reflected through low wave heights) was insufficient to cause the agitation of large diameter particles and explains their absence.

4.20 SPATIAL AND TEMPORAL SEDIMENT CHARACTERISTICS

4.21 SPATIAL VARIABILITY

The tabulated data illustrates the initial findings of this investigation and suggests possible relationships between the variables. However, to account for spatial variability, this investigation must consider the statistical significance of the relationship between site (depth differentiation) and the amount of sediment collected at each site. In order to do so, analysis of variance (ANOVA) test is used. Reference to this statistical technique is made by Clark and Hosking (1986). Analysis of variance is a statistical method which takes the total variability in the complete set of dependent variable scores and divides that total variability into components that can be attributed to different sources. The variances attributed to these different sources are then used to form F Ratios, which can be tested for significance. Since the numerator and denominator variances represent different sources of variability, the F term reflects the relative amounts of variability that can be attributed to these sources. A significant F term is taken to mean that the different sources contribute significantly different amounts to the total variance (Horvath, 1985). The Fisher F distribution serves as the basis for comparison. SAS was utilized to determine the appropriate calculations.

A one way or single factor ANOVA is used to test the null hypotheses that there is no significant difference between the amount of sediment collected and any of the variables in the study. The results of the one way ANOVA are illustrated in Table 4. The significance level is set at 0.05. Since the F-observed value is greater than the F-critical value, the relationship is considered significant. Thus, time and site are both main effects and are considered to contribute significantly different amounts to the total variance.

Now that the significance of both time and site has been established, a one way ANOVA is used to test the null hypothesis that there is no significant difference between the amount of sediment collected at each site at one instance. The results are illustrated in Table 5.

The significance level is set at 0.05. In order for the results to be significant, the F-observed value must be greater than the F-critical value at the 0.05 level of significance. From Table 5 it is seen that the between sites F Ratio is not significant. Thus, the null hypothesis is accepted and it is inferred that in fact significant differences do not exist between sites in this investigation. This is not expected since initial examination reveals that different depths are responsible for trapping different amounts of sediment. In order for this relationship to be significant, perhaps more sediment traps should be installed to increase the degrees of freedom for this test.

Finally, a one way ANOVA is used to test the null hypothesis that there is no significant difference between the amount of sediment collected at each site over time. The results are illustrated in Table 6.

The significance level is set at 0.05. In order for the results to be significant, the F-observed value must be greater than the F-critical value at the 0.05 level of significance. From Table 6 it is seen that the between sites F Ratio is significant. Thus, the null hypothesis is rejected and it is inferred that in fact significant differences do exist over time for each site in this investigation. This result is expected because the predicted wave height and wave period are observed to change over time. The stronger the winds, the higher the wave height and the more energy that is transferred in the nearshore zone.

TABLE 4

ONE WAY ANOVA FOR MAIN EFFECTS

Source	d.f.	S.S.	M.S.	F Ratio
site	10	13686.4	1368.6	5.11*
time	18	4817.2	267.6	
Total	28	18503.6		

(F crit =2.45) * significant at the 0.05 level

TABLE 5

ONE WAY ANOVA FOR SPATIAL VARIATION

Source	d.f.	S.S.	M.S.	F Ratio
site	4	2152.7	538.2	0.79
residual	24	16350.9	681.3	
Total	28	18503.6		

(F crit = 2.78)

TABLE 6

ONE WAY ANOVA FOR TEMPORAL VARIATION

Source	d.f.	S.S.	M.S.	F Ratio
site	6	8691.9	1448.7	3.25*
residual	22	9811.6	445.9	
Total	28	18503.5		

(F crit = 2.55) *significant at the 0.05 level

Since the variation between all of the sites over time is significant, it can be further decomposed by testing with a Newman-Keuls procedure(Winer,1971). The Newman-Keuls test is based on the null hypothesis that there is no difference between the means of each time sampled (Table 7). This procedure focuses on a series of ranges whereby, each value is ranked from lowest to highest, and differences are calculated between each time interval. These ranked means are then compared to a studentized range which is a test criterion. The significance level is set at 0.05 and once the critical difference is calculated, a region of rejection has been defined. Examination of Table 7 reveals that since the observed value does not exceed the critical value in all instances, that the null hypothesis must be advanced. That is, there is no significant difference between the means of each time sampled.

TABLE 7

NEWMAN-KEULS TEST FOR TEMPORAL MEANS

T	T3	T2	T1	T4	T6	T5	T7
Mean	3.6793	6.5118	11.0401	21.5214	21.5965	36.7988	62.0701
T3 3.6793	-----	2.8325	7.3608	17.8421	17.9172	33.1195	58.3908*
T2 6.5118		------	4.5283	15.0096	15.0847	30.2870	55.5583*
T1 11.0401			------	10.4813	10.5564	25.7587	51.0300*
T4 21.5214				------	0.0751	15.2774	40.5487
T6 21.5965					------	15.2023	40.4736
T5 36.7988						------	25.2713
T7 62.0701							------
Critical Difference	31.15	37.80	41.82	44.67	46.99	48.78	

* = significant at the 0.05 level

4.22 SUMMARY OF ANALYSIS OF VARIANCE

Although the results of the graphs in section 4.1 are encouraging, this confidence is not generally reinforced by statistical inference. Initially, time and site are both found to be main effects and are inferred to contribute significantly different amounts to the total variance. Further, the variance accounted for by all of the time intervals together is also significant. Collectively, the time intervals do display a significant difference in the amount of sediment collected. Beyond this, the ANOVA test for all of the sites together conclude that the amount of sediment collected at all depths is not statistically significant regardless of which depth the trap is placed at. In an attempt to evaluate each time interval against the other, Newman-Keuls is used to test for differences between all pairs of means obtained in the Analysis of Variance. The results of this test demonstrate that statistically significant differences existed between T3, T2, T1 and T7. T7 represented a particularly active period of sediment flow associated with the beginning of the fall season. However, the inclusion of more sediment traps collected over a longer time interval would enhance the sampling scheme for stronger statistical results.

4.3 TWO DIMENSIONAL WAVE PREDICTION MODEL

4.31 COMPUTER GENERATED WAVE HEIGHT AND WAVE PERIOD

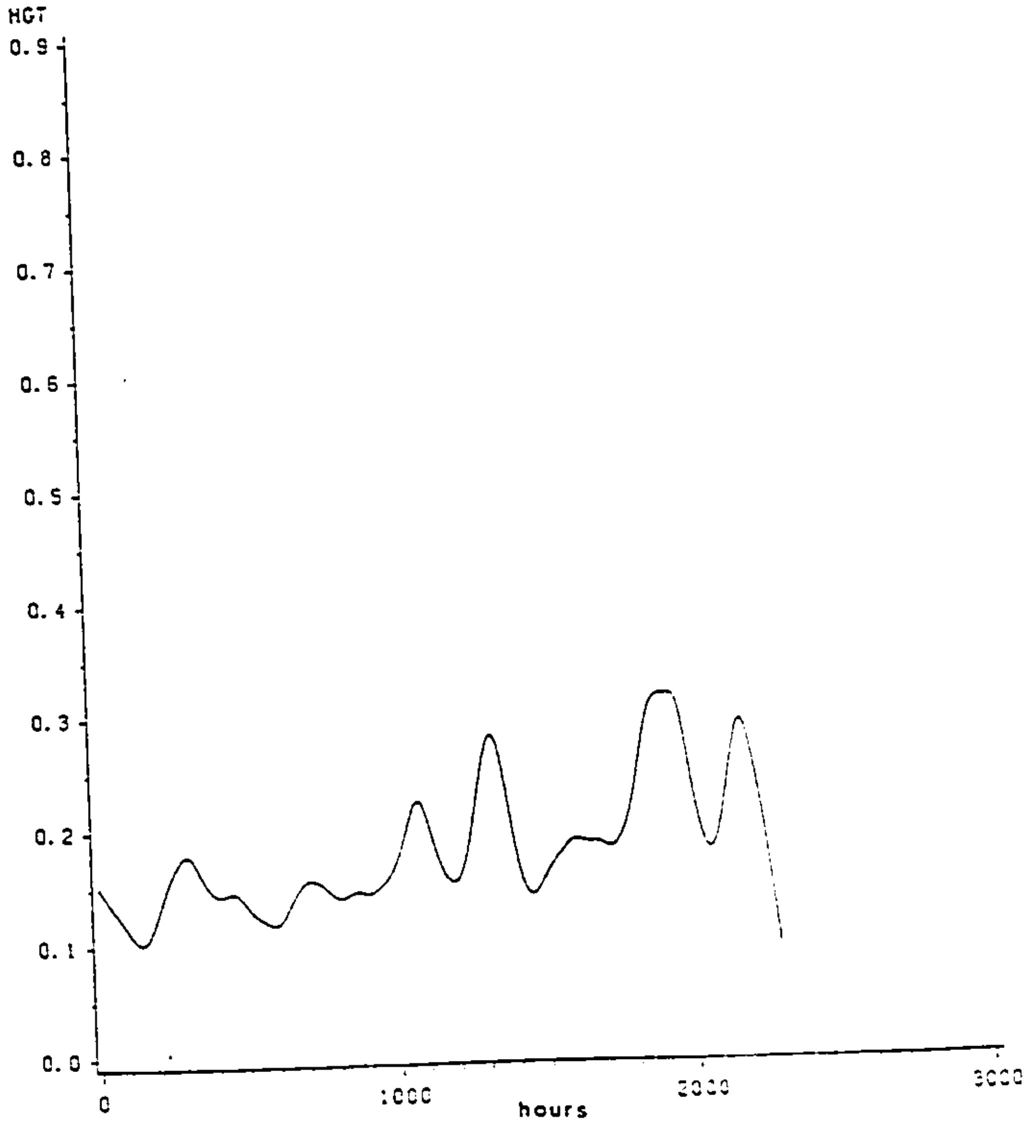
As previously mentioned, the Two Dimensional Lake Wave Prediction System model is used to generate predicted wave heights and periods for this investigation. Graphs of hourly wave height and wave period over ten day intervals for the sampling period July 1 to September 29 can be found in Appendix C. Figure 13 and Figure 14 summarize this data by illustrating predicted wave height in metres and predicted wave period in seconds for July 1 to October 2, 1988.

On first inspection, these values appear to be unrealistically small. It is noted by investigators who have tested this model (Schwab, 1983 and Liu, 1984) that due to deep water assumptions implicit in the program, the prediction for shallow water wave height and wave period underestimates reality. However, since this underprediction is constant throughout the entire sampling interval (July to September) the relative amounts of increase or decrease in predicted wave height and predicted wave period are a valid representation of change over time. For this reason, the wave model is still useful to compare predicted conditions to amounts of sediment collected in order that a temporal relationship be examined. As of yet, there is no program in existence which accurately calculates nearshore parameters. For purposes of wave height and wave period predictions, the Two-Dimensional Lake Wave

FIGURE 13

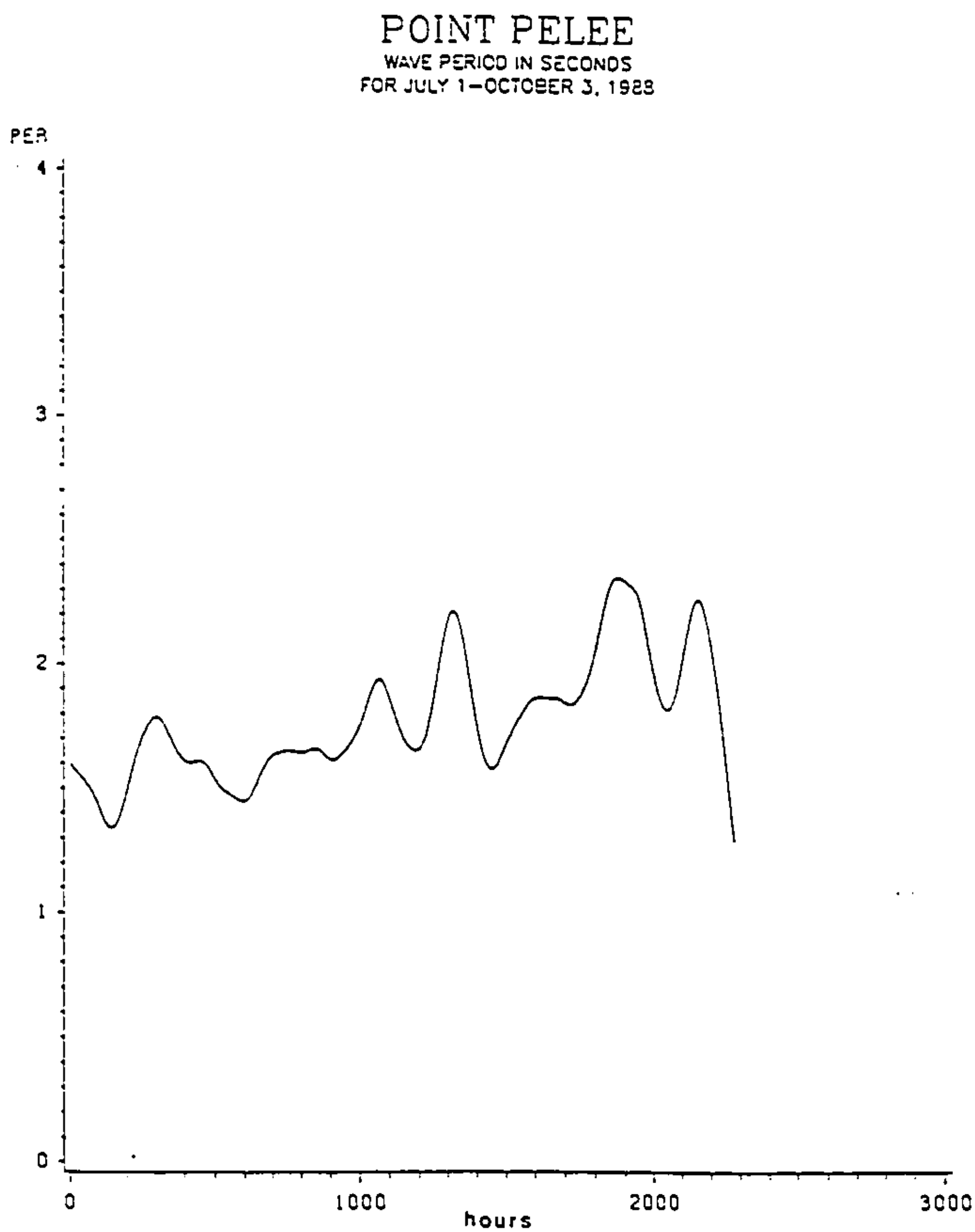
POINT PELEE

WAVE HEIGHT IN METRES
FOR JULY 1 - OCTOBER 3, 1988



SOURCE: PARKS CANADA, 1988

FIGURE 14



SOURCE: PARKS CANADA, 1988

Prediction System is the best model to date (personal communication with D. Schwab, August 23, 1989).

Figure 13 and Figure 14 can be compared to the average amount of sediment collected at all five stations over each time interval to provide an initial notion of the relationship between sediment mass and predicted wave height.

One may expect a direct relationship between predicted wave height and the amount of sediment collected. That is, as wave height increases, the amount of sediment also increases. Table 8 compares average wave height and wave period over each sampling period to the amount of sediment retained in the traps during that same period. Average wave height and wave period was calculated for each day. These daily averages were summed and divided by the number of days prior to each sampling period.

TABLE 8

AVERAGE WAVEHEIGHT AND WAVEPERIOD FOR JULY 5 TO SEPTEMBER 29

Date	Average Wave Height (m)	Average Wave Period (s)	Average Mass of Sediment (g)
July 5	0.1376	1.6884	11.0401
July 20	0.1439	1.5993	6.5118
Aug 3	0.1377	1.5713	6.5118
Aug 17	0.1664	1.7152	21.5214
Aug 30	0.1866	1.8315	36.7988
Sept 15	0.1944	1.8632	21.5965
Sept 29	0.2786	2.2379	62.0701

From Figures 13 and 14, a net increase in predicted wave height and predicted wave period is observed during September and October. The slope of the line for both graphs is increasing during these two months. This net increase is also reflected in the average mass of sediment trapped over each period. By observation, there exists a direct relationship between the average wave height and period for each interval and the amount of sediment collected over that same interval of time. Since September and October are the start of the storm season, it is expected that more energy will be present in the nearshore zone to suspend particles. Thus, the wave conditions in the limnetic environment play an important role in sediment masses collected and settling fluxes in the nearshore zone.

4.32 SEDIMENT MASS AND TRAP DEPTHS

Figures 15 to 21 depict the relationship over time between the mass of sediment in grams, the location of each sediment trap at a different depth and the predicted average wave height prior to each sampling interval. The predicted average wave height for the period prior to each collection period is incremented in ten thousandths of a metre in order that SAS(1985) would plot the values in a three dimensional format. This incrementation is negligible and is not considered to affect the data portrayal.

FIGURE 15

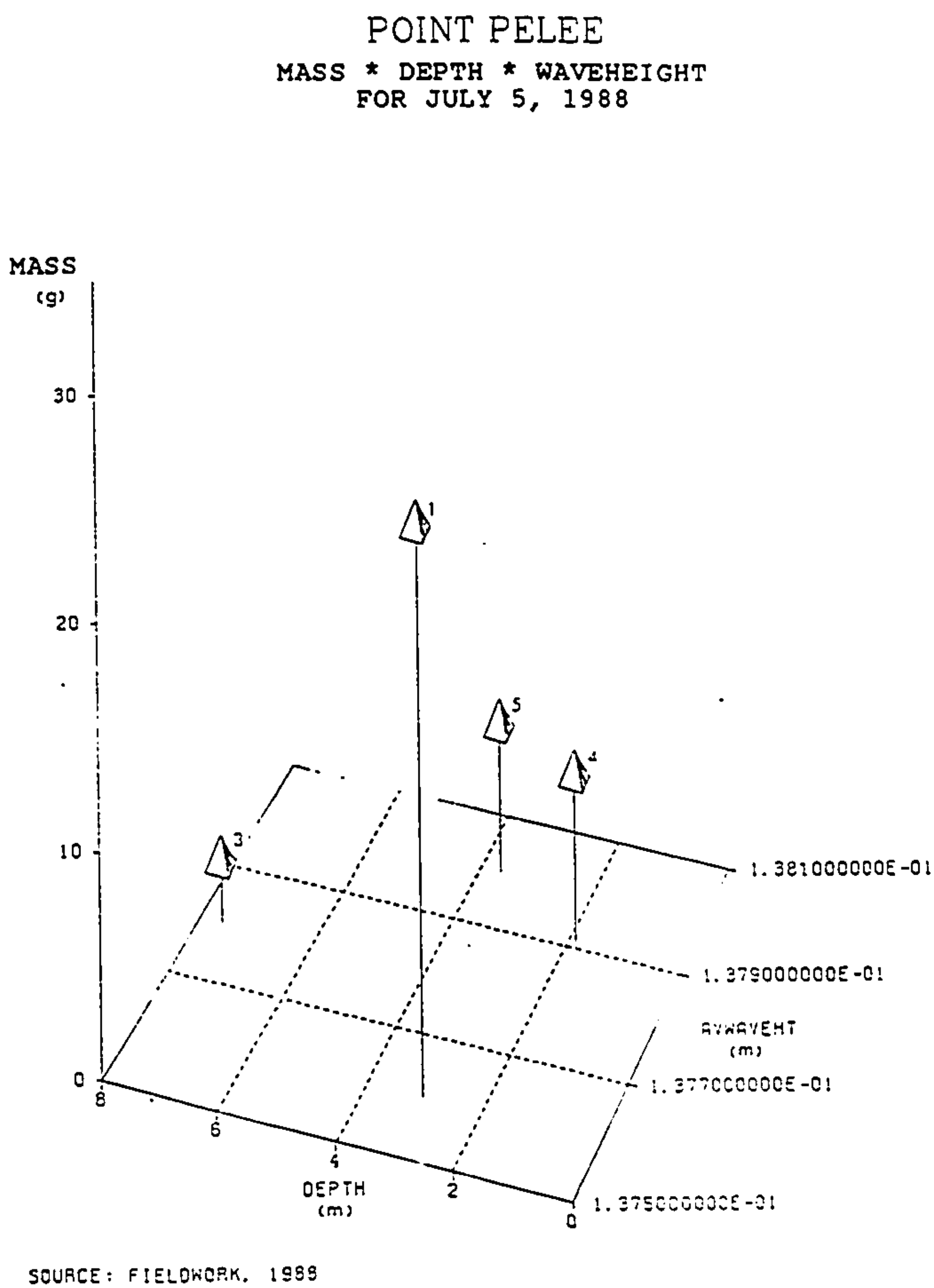
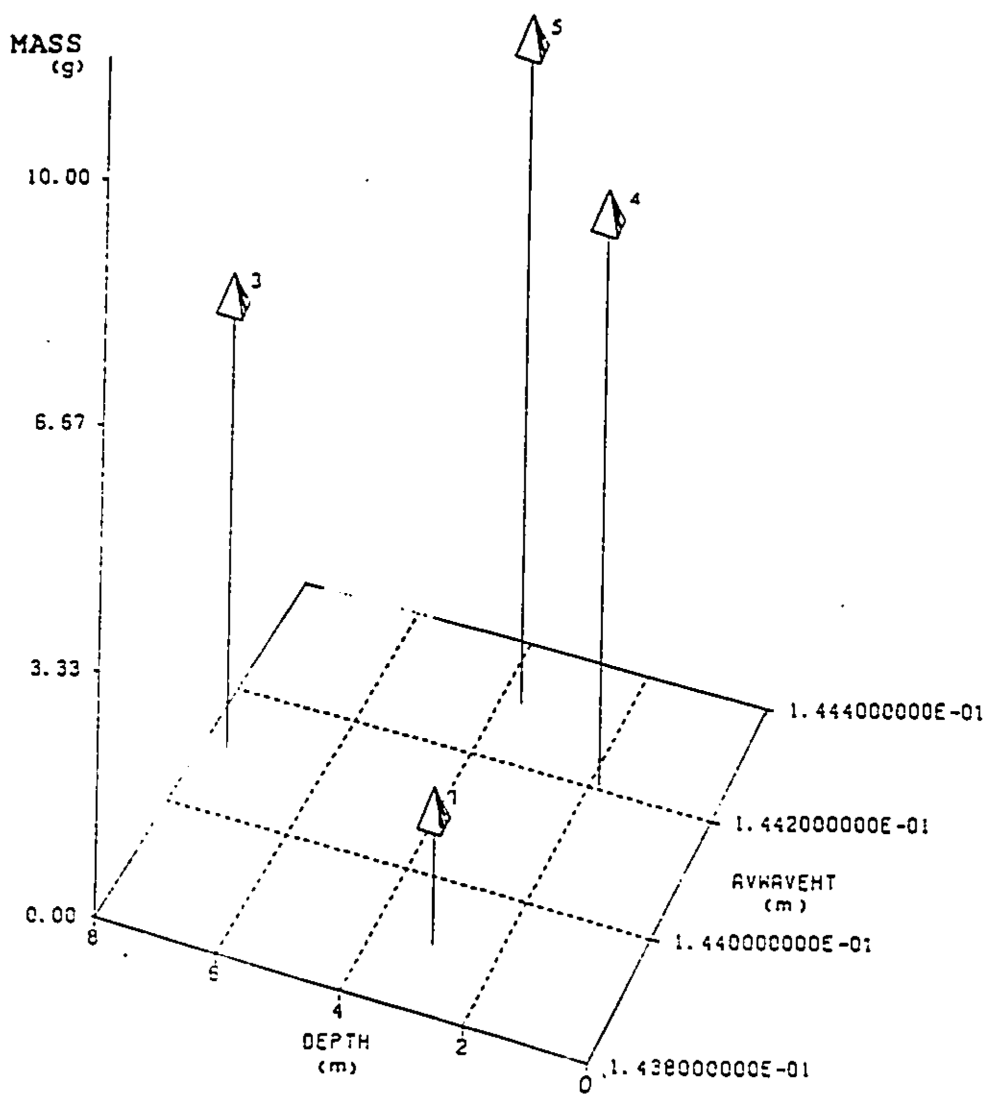

POINT PELEE
MASS * DEPTH * WAVEHEIGHT
FOR JULY 5, 1988
MASS
(g)
30
20
10
0
1
5
4
3
1.3810000000E-01
1.3790000000E-01
AVWAVEHT
(m)
1.3770000000E-01
1.3750000000E-01
8
6
4
2
0
DEPTH
(m)
SOURCE: FIELDWORK, 1988

FIGURE 16

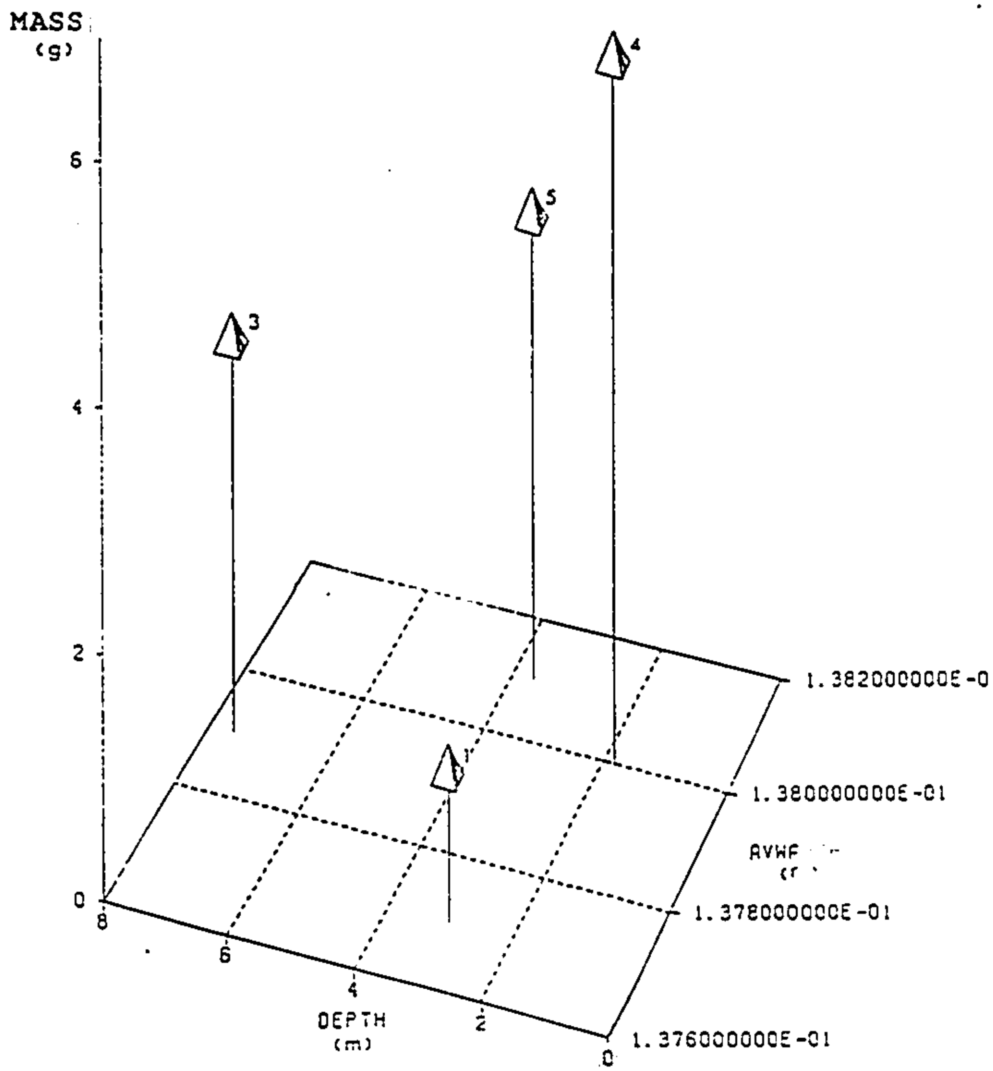
POINT PELEE
MASS * DEPTH * WAVEHEIGHT
FOR JULY 20, 1988



SOURCE: FIELDWORK, 1988

FIGURE 17

POINT PELEE
MASS * DEPTH * WAVEHEIGHT
FOR AUGUST 3, 1988



SOURCE: FIELDWORK, 1988

FIGURE 18

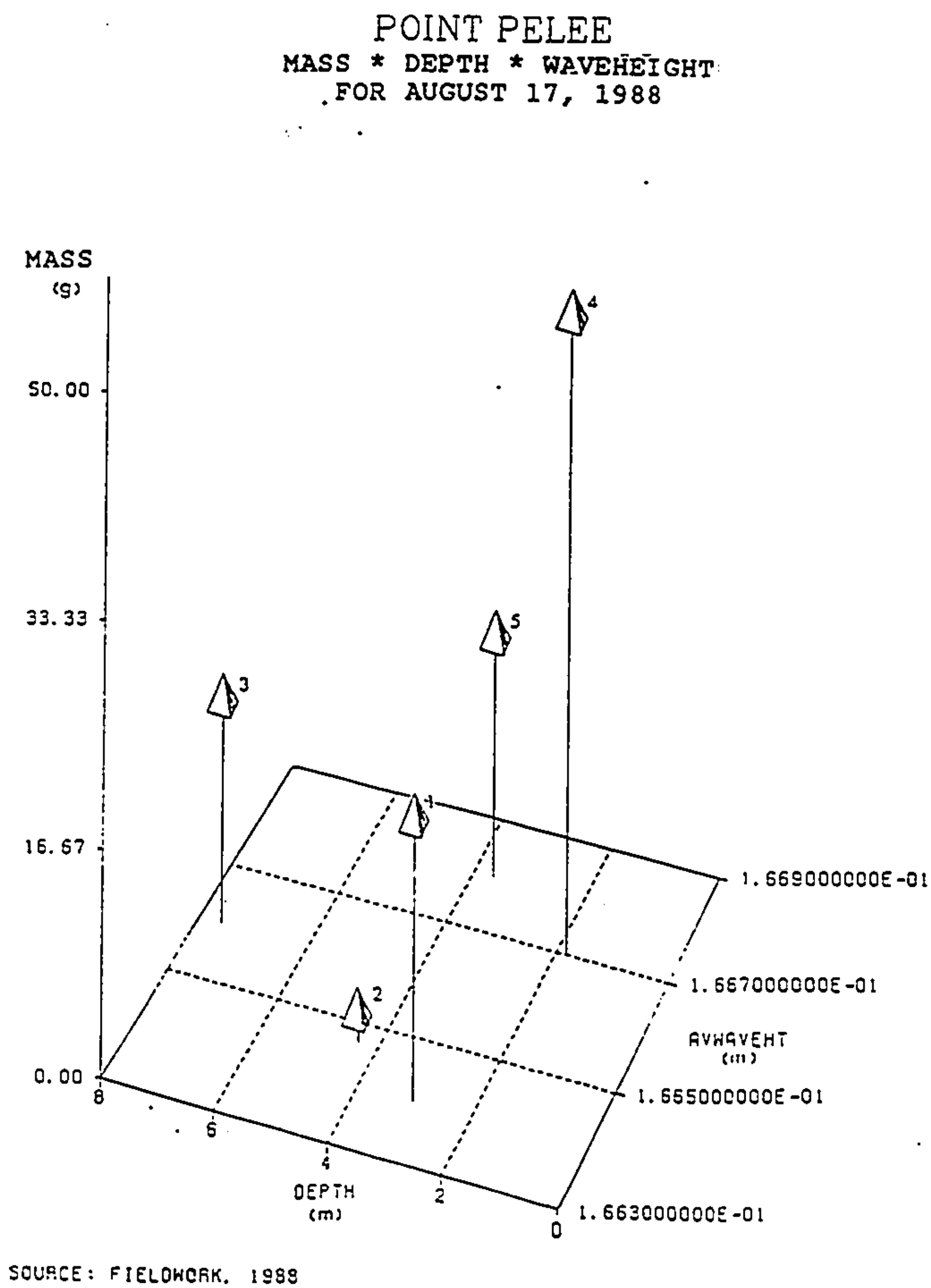
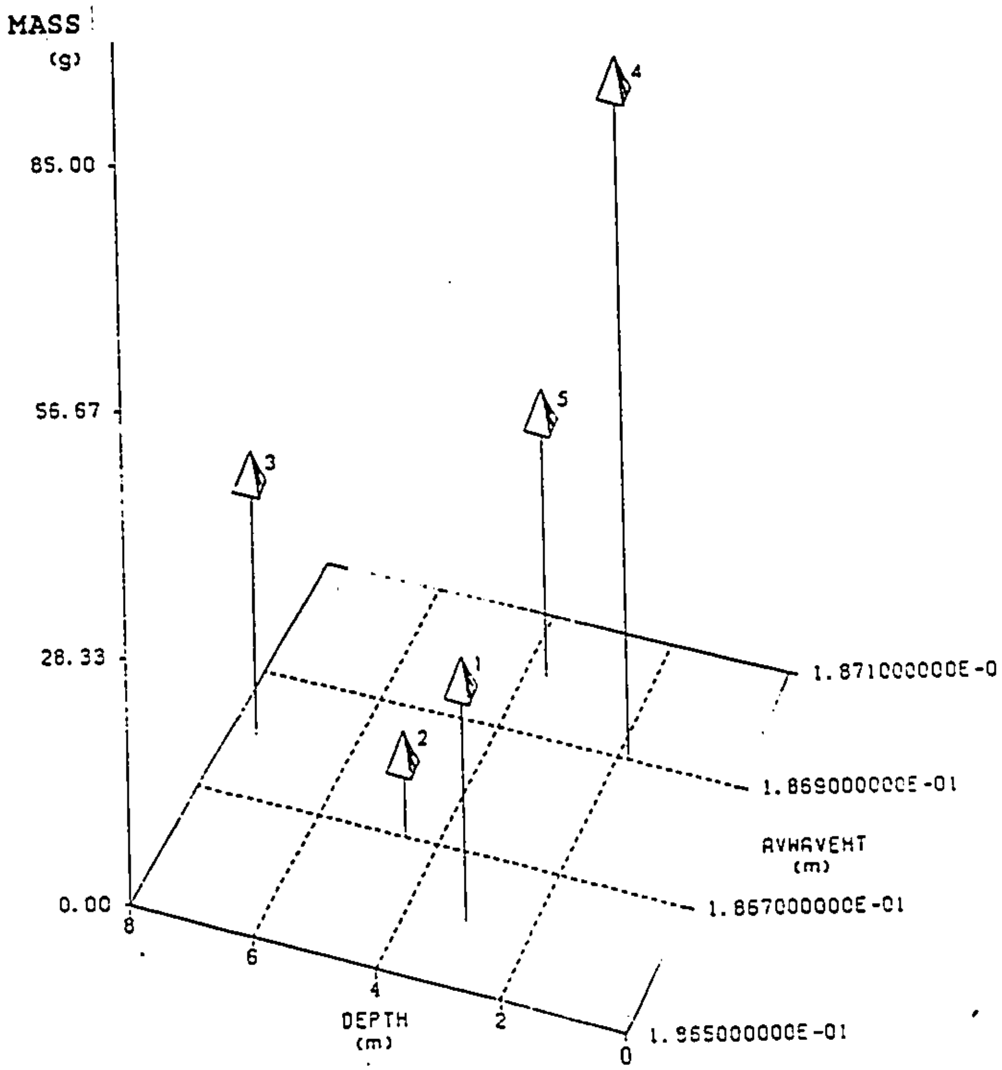

POINT PELEE
MASS * DEPTH * WAVEHEIGHT
FOR AUGUST 17, 1988
MASS
(g)
50.00
33.33
16.67
0.00
8
6
4
2
0
DEPTH
(m)
1.669000000E-01
1.667000000E-01
AVWAVEHT
(m)
1.665000000E-01
1.663000000E-01
SOURCE: FIELDWORK, 1988

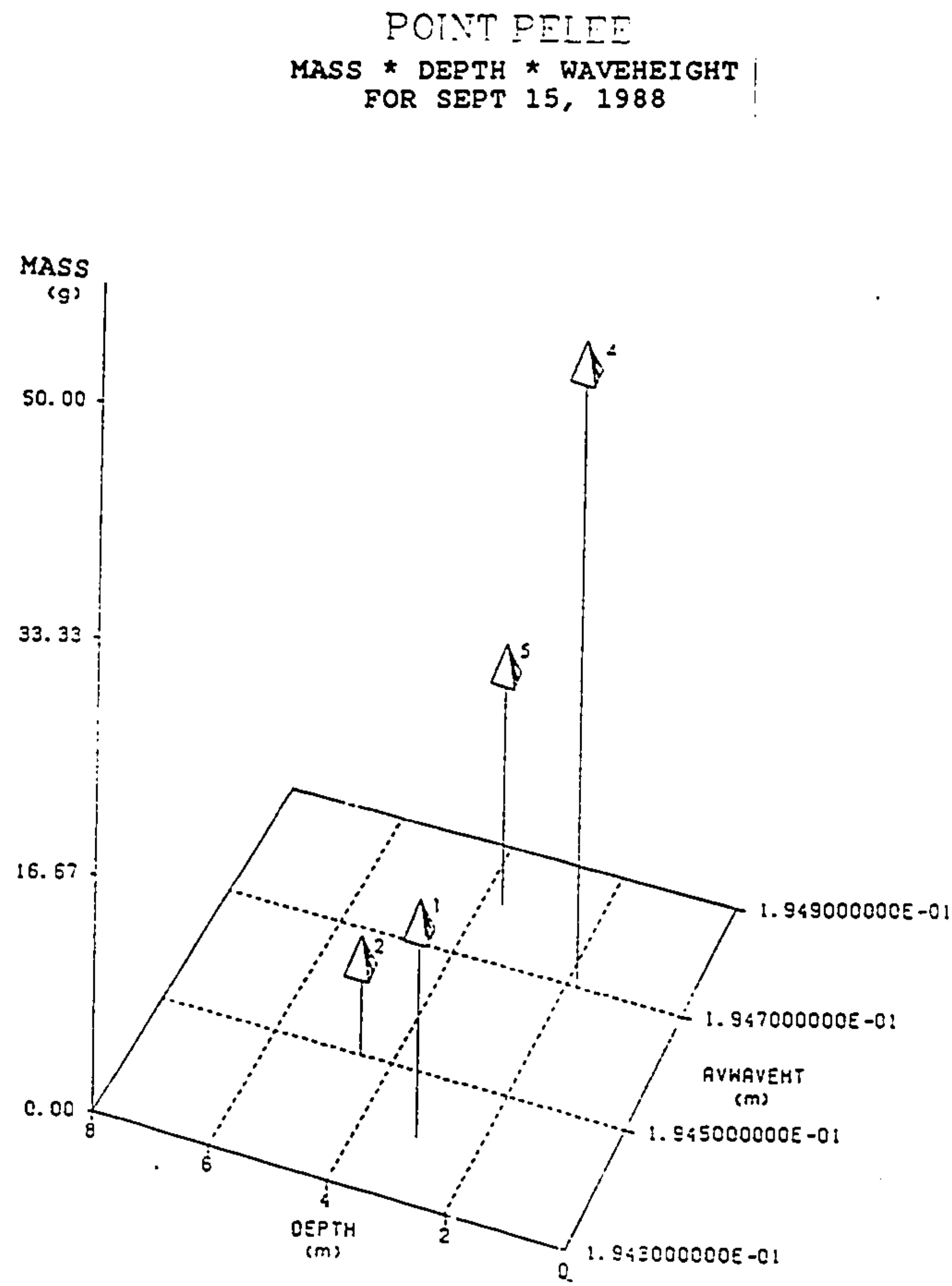
FIGURE 19

POINT PELEE
MASS * DEPTH * WAVEHEIGHT
FOR AUGUST 30, 1988



SOURCE: FIELDWORK, 1988

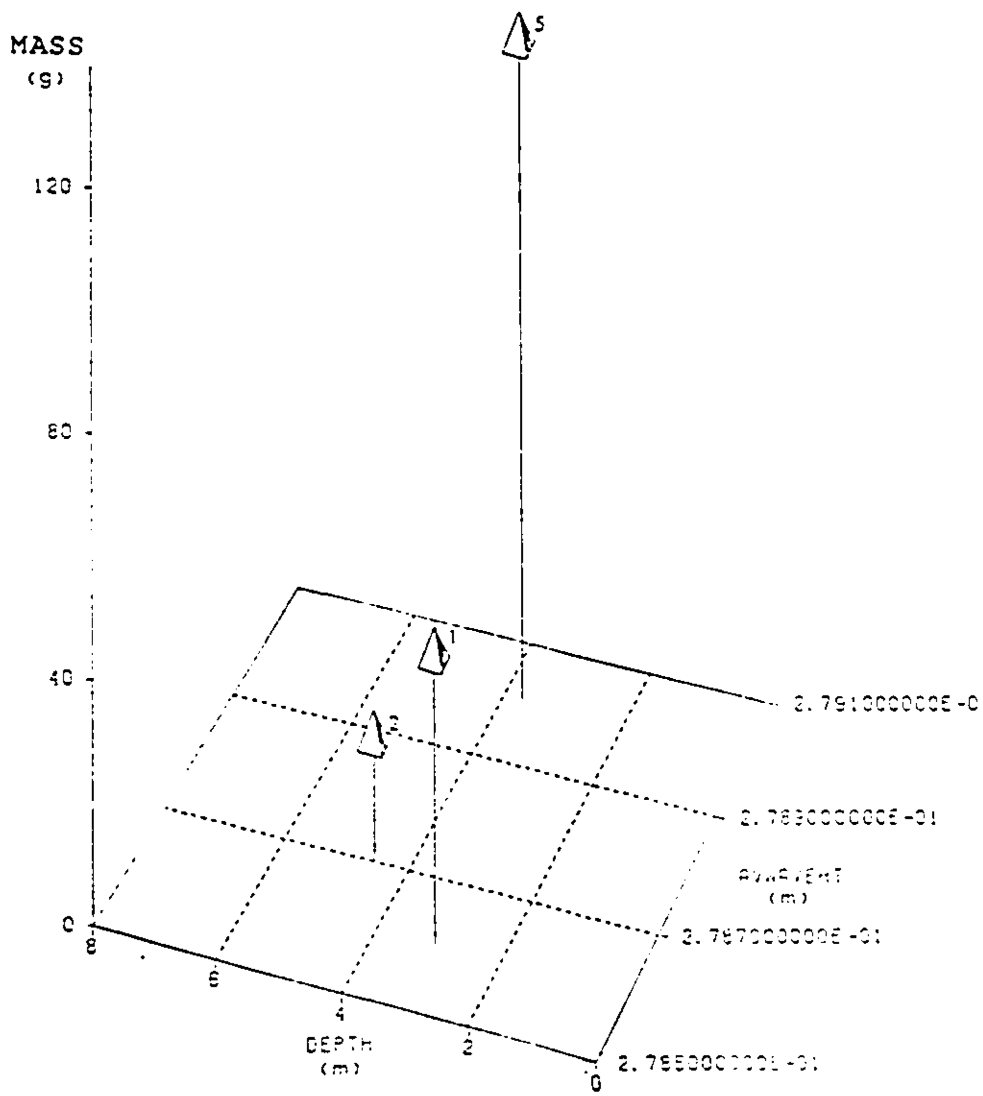
FIGURE 20



SOURCE: FIELDWORK, 1988

FIGURE 21

POINT PELEE
MASS * DEPTH * WAVEHEIGHT
FOR SEPT 30, 1988



SOURCE: FIELDWORK, 1988

Recall that:

a) the site numbers, in order of increasing depth, are 4,1,5,2 and 3.

b) sites 1,2, and 3 are on the eastern shore while sites 4 and 5 are located on the western shore of Point Pelee

The average wave height for the July 5 sample is 0.1376 metres. July 5 shows sites 1 and 4 collecting the most sediment (Figure 15). Variation within the shallower traps may be accounted for by the fact that sites 1 and 2 were located on the eastern nearshore zone of the tip while sites 3,4 and 5 were on the western side. Coakley(1980) suggests that transportation rates differ between the eastern and western shores of Point Pelee due to different local currents and different fetches. Sites 3 and 5 were responsible for less sediment while site 2 was inoperable.

The average wave height for July 20 was 0.1439 metres. Figure 16 illustrates east-west variability more clearly. Although 1 and 4 are the shallowest, the traps on the western shore (3,4,5) caught more sediment in this instance.

This is due to the fact that winds from the east and north east are less frequent than those from the west. The greater the duration of a western wind, the higher the wave height and the greater the wave regime of the western shoreline.

Figure 17 (August 3) demonstrates a similar relationship to the previous collection. Average wave height for this period was 0.1377 metres. However, within the western zone, the shallowest trap (4) caught the most sediment followed in order of increasing depth by traps 5 and then 3.

In Figure 18 and Figure 19 (August 17 and 30) the two traps in the eastern zone (1 and 2) collected less sediment than the west again. Within each zone, the traps collected less sediment with increasing depth. Average wave heights for these two periods were 0.1664 metres and 0.1866 metres, respectively.

By September 15, (Figure 20) site 3 had disappeared, but the eastern traps were still collecting less sediment than the western ones. Average wave height for this period was 0.1944 metres.

The last collection (September 29) is illustrated in Figure 21. By now, traps 3 and 4 are inoperable, yet, the eastern shore still indicates lower sediment masses than the western nearshore zone. Average wave height for this final interval is 0.2786 metres.

Although the storm season is approaching by September and October, the presence of stronger winds of greater duration does not change which shore experiences the greatest sediment mass. Rather, the increasing energy brought about by changing conditions changes the sediment mass over the entire nearshore zone rather than one shore over another.

From these graphs, relationships between sediment mass, wave height and the installation depth can be developed. An inverse relationship exists between depth and sediment mass.

The results indicate that as depth increases, sediment mass decreases in the nearshore zone. In addition, proximity to the tip of Point Pelee also influences sediment mass. In this investigation, the western nearshore zone is responsible for the catchment of more sediment than the eastern zone. This is due to the previous notation that winds of the greatest magnitude in the summer blow from the west rather than from the east and north east.

Spatial variability is therefore accounted for by the actual depth that the trap is located at as well as its exposure to different nearshore conditions depending on which side of the Point the trap lies on.

4.33 UTILITY OF THE MODEL

It is beyond the scope of this thesis to test the Two-Dimensional Lake Wave Prediction System results against observed wave height and wave period. The model has been tested in the past and found to successfully predict wave height, wave period and direction on Lake Erie (Bishop,1983; Donelan,1984; Schwab, Bennett and Lynn, 1986;). It is acknowledged that error may stem from shallow water effects since the shallow water limit on wave height has not been included in the model. In this investigation, the model is found to underpredict wave height and wave period. It underpredicts constantly, however, which lends itself to relative comparisons against the amount of sediment caught.

Although the generated wave height and wave period values are low, they do demonstrate an increase as the storm season approaches, which is expected. This increase in September values for wave height and wave period compliments the increase in sediment trapped for the same time period. It is inferred, therefore, that an increase in wave height will be reflected by an increase in the amount of sediment retained in each trap.

5.0 SUMMARY AND CONCLUSIONS

5.1 SEDIMENT TRAPS

Sediment traps appear to be an effective means to account for spatial and temporal variability of sediment mass in the nearshore zone of Point Pelee. The traps located in shallow water (sites 1,4 and 5) retain more sediment than those in deeper water (sites 2 and 3). This is expected as wave action plays an increasingly important role in the movement of sediments as the nearshore zone is approached.

The mass of sediment trapped at each sampling interval is also indicative of nearshore conditions over time. The first three collection periods correspond to low energy regimes (lower wave height) and indeed are significantly less than the last four samples. As the storm season approaches by September and October, wave height increases (higher energy regime) and a direct relation is observed between the average amount of sediment collected at each time interval and increasing energy.

The actual particles deposited in the sediment traps range from fine sand to medium clay in size(2 to 10 o). This is again expected as the low energy environment present at Point Pelee during the sampling period would be incapable of suspending particles of a large diameter. As well, the sediment moving near the bed has not been accounted for. This bedload would probably contain most of the particles of a larger diameter.

5.2 THE TWO-DIMENSIONAL LAKE WAVE PREDICTION SYSTEM

The acquisition and installation of a Waverider mechanism in the nearshore zone of Point Pelee for the duration of the sampling period was economically unfeasible. Because information was available on the wind climate of Point Pelee on an hourly basis, computer simulation was used to gain information on the limnetic environment. The Two-Dimensional Lake Wave Prediction System which is used has been tested by previous authors (Schwab et al., 1984) and found to agree very well using wave height measurement of 1.5 metres with a correlation of 0.93 and a standard error of 20 cm. Additional fieldwork at a different location in Lake Erie found that actual wave height measurement were consistently higher than the modelled wave height although the correlation was 0.88.

As with any model, there are certain limitations to its application. Due to deep water assumptions implicit in the model, wave height and wave period are also underestimated in this study. Since this model has been previously observed to underestimate consistently in Lake Erie, it is not acceptable to attempt to quantify any absolute parameters in the nearshore zone in the absence of field measurements of wave height and wave period. However, this consistency does enable valid observation in relative terms of the trends present in the nearshore zone over time.

5.30 TRENDS OVER TIME AND SPACE

Although the previous graphs support the hypotheses of this study by the indication of a relationship between the amount of sediment caught at each site over time, these results are not statistically supported. One way Analysis of Variance tests are employed in an attempt to test for the proportion of variance attributable to each variable.

Time and site (depth) are found to be main effects and are inferred to contribute significantly different amounts to the total variance. When broken down, the time intervals collectively display a significant difference in the amount of sediment collected and are then tested using Newman-Keuls test procedure. However, the results of Newman-Keuls test do not demonstrate any significant differences in the means calculated by the Analysis of Variance. At this point, I am no longer able to advance the hypotheses. Examination of all of the sites together reveals that the amount of sediment collected at all depths is not statistically significant regardless of which depth the trap is installed at.

The statistical analysis could be strengthened by the inclusion of more sites, possibly two or more at the same depth, to enable the creation of a) within cell variance at the same depth and b) between cell variance at different depths over time. This would allow the use of a two way ANOVA to account for variability in the study. In addition, more samples could be taken to extend the sampling design for a greater degree of confidence.

5.31 TRENDS IN WAVE HEIGHT AND SEDIMENT MASS

When average wave height and average wave period is compared to the average mass of sediment deposited in all of the traps for each time interval, a direct relationship between increasing wave height and increasing amounts of sediment can be seen. The shallower traps are responsible for more sediment than the deeper ones. This is expected as more energy is present in the shallow regime to suspend particles.

It is also noted that proximity to the tip plays a role in sediment deposition. In this investigation, the western nearshore zone is responsible for the catchment of more sediment than the eastern shore. This is attributable to localized currents in combination with the fact that in the summer, the winds of greatest magnitude blow from the west rather than from the east.

5.4 RECOMMENDATIONS

This investigation has applied the methodology of sediment trap technique to a unique region of the nearshore zone in an attempt to replicate experimental conditions in an untested environment. Sediment traps have been found to be an economical means to quantify settling rates in the nearshore zone. In future investigation, it is recommended that increasing numbers of traps be installed and sampled more often for a longer period to enhance statistical stability of this type of experiment.

The utilization of the Two-Dimensional Lake Wave Prediction System in this study has a number of advantages. Actual wave height and wave period measurements are costly. Since hourly wind data is readily available from Parks Canada, this simulation is the best way to obtain information on predicted wave height and wave period. In addition, the data is presented in a legible and useful format.

However, this method of predicting wave height and wave period also has disadvantages. Shallow water limits on wave height have not been included in this model. This leads to underestimation of wave conditions in shallow water regimes during calm conditions. Previous testing has indicated that the model underrepresents reality consistently and therefore the generated trends in conditions are valid in relative terms. What is not known is how much the model underpredicts actual wave height and wave period in the nearshore zone. For this reason, it is not correct to quantify in absolute terms the measured difference between the modelled wave height and the actual wave height.

In conclusion, the results of this investigation allow recommendation of the continued use of sediment traps to account for sedimentary conditions in the nearshore zone. It is advised that the use of this particular computer model be carefully applied by other researchers. The trends portrayed by predicted wave height and wave period over time are valid. The absolute amount of estimated wave height deviation from actuality is another matter. In absence of any other programs, the Two-Dimensional Lake Wave Prediction System is the most appropriate to date. However, it is recommended that extreme caution be exercised when drawing conclusions based on the actual measurement of wave height and wave period in the nearshore zones of Lake Erie.

APPENDICES

APPENDIX I

WEATHER DATA

WIND-MILES PER HOUR AND DIRECTION

MONTH July 1988

○ = sampling day

HOURS

	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	01	02	03	04	05	06	07
1	NW 9	NW 10	N 12	N 13	N 12	N 13	NW 12	NE 11	NE 10	NE 8	NE 6	NE 7	NE 6	NE 5	N 5	N 5	N 5	N 4	N 3	NW 3	NW 3	N 2	N 1	SW 2
2	SW 3	SW 5	SW 5	SW 6	SW 6	SW 6	SE 6	SE 9	SE 10	SE 9	SE 8	SE 8	SE 6	SE 6	SE 6	S 4	S 4	S 2	S 1	S 3	SW 3	SW 3	SW 3	SW 3
3	SW 4	SW 5	SW 4	SW 5	SW 5	SW 5	SE 6	SE 7	SE 8	SE 6	SE 7	SE 6	SE 7	SE 7	SE 6	SE 5	NE 4	NE 4	NE 2	NE 1	NE 2	NE 1	NE 2	E 3
4	SE 6	E 7	SE 7	SE 8	SE 9	SE 7	SE 8	E 9	E 9	SE 7	SE 7	SE 6	E 5	SE 6	SE 6	E 5	E 5	E 4	E 3	E 2	E 2	E 4	E 3	E 4
5	SE 6	SE 5	SE 6	SE 6	SE 7	SE 7	SE 6	SE 6	SE 6	SE 4	SE 5	SE 5	SE 5	SE 6	SE 5	SE 6	S 4	S 4	SW 1	SW 1	S 1	S 1	S 1	SE 1
6	SW 3	SW 2	SW 3	SW 4	SW 4	SW 5	SW 3	SE 5	SE 5	SE 3	SE 5	SE 4	S 3	S 4	S 2	SW 4	SW 6	SW 5	SW 3	W 2	C	C	C	C
7	SW 3	SW 4	SW 5	SW 5	SW 5	SW 5	SW 5	SW 2	SE 3	S 2	SW 3	SW 5	SW 5	SW 4	C	C	E 1	NW 1	NW 1	C	C	NW 2	NW 4	NE 4
8	NE 4	SW 2	SW 4	SW 5	SW 5	SW 5	SW 5	SW 5	SW 4	SW 4	SW 2	SW 4	SW 3	W 1	W 2	NW 2	NW 5	NW 5	W 5	W 6	W 6	NW 11	W 5	W 5
9	W 6	SW 7	SW 7	SW 7	SW 8	SW 7	SW 8	SW 6	SW 6	SW 6	SW 4	SW 4	SW 4	SW 4	SW 5	SW 5	SW 4	SW 4	SW 3	SW 2	NW 2	S 4	SW 5	SW 8
10	W 9	W 10	NW 11	NW 10	W 6	SW 6	SW 6	SW 3	E 3	SE 3	SW 2	SE 4	NW 13	SW 8	S 3	S 7	SE 7	SW 8	SW 8	SW 9	SW 10	SW 9	NW 10	NW 5
11	NW 6	SW 6	W 8	SW 7	SW 9	SW 5	SW 7	SW 6	SW 7	SW 5	SW 6	SW 6	SW 6	SW 5	W 5	NW 6	NW 6	NW 7	NW 6	NW 7	N 5	N 4	N 5	N 6
12	NE 7	NE 5	NE 4	SE 5	SE 5	SW 6	SW 7	SW 7	SW 7	SW 4	SW 3	C	NE 4	NE 7	NE 6	E 6	SE 6	SE 6	SE 5	SE 5	SE 5	SE 5	SE 5	SE 9
13	SE 11	SE 10	SE 9	SE 7	SE 8	SE 8	SE 8	SE 8	SE 8	SE 8	SE 8	SE 7	S 7	SW 8	SW 9	SW 9	SW 11	SW 10	SW 11	SW 12	SW 12	SW 12	SW 11	SW 8
14	SW 12	SW 11	SW 10	SW 11	SW 11	SW 12	SW 10	SW 7	SW 7	NE 6	NE 7	NE 6	NE 4	N 5	NE 6	NE 6	NE 7	NE 4	NE 4	NE 3	NE 4	E 4	E 4	SE 4
15	SE 4	SE 6	SE 6	SE 6	SE 6	SE 5	SE 6	SE 7	SE 7	SE 4	SW 6	SW 10	SW 8	SW 6	SW 4	SE 6	SE 5	S 4	S 3	S 2	S 4	SW 6	SW 6	SW 6
16	SW 7	SW 7	SW 7	SW 7	SW 7	SW 6	SW 8	SW 7	SW 7	SW 5	SW 9	SE 4	SE 9	NE 11	NE 8	NE 6	NE 6	SE 7	SE 11	SE 9	SW 9	NW 10	NW 12	NE 11
17	N 11	NW 7	NW 4	NW 6	W 6	SW 7	SW 8	SW 7	SW 6	SW 4	SW 5	S 3	SW 4	S 3	S 3	S 3	S 3	S 3	S 4	S 3	S 2	S 4	S 3	SW 4
18	SE 4	SE 6	SE 6	SE 7	SE 5	NE 5	NE 5	NE 7	NE 6	SE 7	SE 12	SE 8	SE 3	SE 4	S 6	S 6	SW 7	SW 8	SW 8	SW 8	SW 6	N 4	N 5	NE 5
19	NE 5	NE 6	NE 6	NE 5	NW 7	NE 9	NE 11	NE 8	NE 9	NE 7	NE 6	NE 5	N 5	N 5	N 5	NE 4	N 4	NE 4	NE 5	N 4	NE 6	NE 8	NE 9	NE 8
20	NE 6	NE 8	NE 7	NE 7	NE 5	NE 4	NE 7	NE 8	NE 9	SE 8	SE 11	SE 11	SE 9	SE 7	NE [illegible]	NE 5	NE 7	NE 7	NE 7	NE 8	NE 5	NE 5	NE 5	NE 8
21	NE 9	→ 9	9	9	NE 5	SE 5	SW 5	→ 6	6	5	SW 3	NW 3	NW 5	NE 4	→ 5	5	NE 4	N 5	→ 5	5	5	N 5	NE 5	NE 6
22	NE 5	→ 2	6	NE 6	SE 5	→ 3	7	7	5	6	SE 4	SW 2	NW 3	NE 6	SE 4	S 3	C	SE 2	N 1	→ 3	3	N 3	E 2	SE 4
23	E 5	E 6	SE 7	E 8	SE 11	SE 9	E 8	E 7	E 8	E 7	E 6	NE 6	SE 7	SE 5	NE 3	NW 4	N 4	N 4	N 4	N 5	N 4	N 4	N 4	N 4
24	N 2	W 5	W 6	SW 6	SW 7	SW 9	SW 9	SW 8	SW 7	SW 5	SW 4	W 5	SW 5	SW 5	SW 6	SW 6	SW 4	SW 3	SW 5	SW 5	SW 6	SW 7	NW 11	NW 9
25	NW 7	SW 2	SW 4	SW 6	SW 6	SW 4	SW 4	SW 4	S 4	SW 5	SW 6	SW 11	SE 8	SE 4	NW 5	W 5	SW 2	SW 5	SW 3	S 1	NW 1	N 2	N 2	NE 5
26	NE 5	NE 4	NE 4	SW 3	SW 4	SW 5	SW 6	SW 5	SW 7	W 4	SW 4	W 2	W [illegible]	SW [illegible]	SW 3	N 3	N 3	N 3	SW 4	SW [illegible]	N 1	N 1	SW 1	W 7
27	W 3	W 4	SW 6	SW 6	SW 6	SW 7	SW 7	SW 6	SW 5	SW 6	SW 7	SW 4	SW 5	SW 1	S 1	SW 4	SW 1	SW 4	SW 6	SW 5	SW 5	SW 7	NW 8	NW 7
28	SW 7	W 7	SW 9	SW 9	SW 11	SW 10	SW 9	SW 7	SW 6	SW 6	SW 4	W 4	NW 2	SW 3	NW 3	NW 2	W 2	SW 4	SW 4	W 3	NW 5	SW 3	W 5	NW 5
29	NW 5	SW 7	SW 7	SW 7	SW 7	SW 6	SW 5	SW 4	SE 4	SE 4	SE 4	SE 5	S 5	SW 7	SW 7	SW 7	SW 9	SW 8	SW 7	SW 8	SW 9	SW 8	SW 9	SW 9
30	SW 10	SW 11	SW 7	SW 7	SW 5	SW 11	SW 13	S 8	SW 9	SW 9	SW 8	W 9	NW 8	SE 6	N 3	NW 3	NW 4	NW 4	N 4	NW 4	N 3	N 3	NE 5	NE 5
31	NE 6	NE 6	SE 5	SW 5	SW 4	SW 4	SW 5	S 4	SW 5	SW 5	S 3	S 3	S 3	S 4	SW 3	SW 4	SW 3	SW 3	S 4	SW 7	SW 8	SW 10	SW 10	SW 8

POINT PELEE NATIONAL PARK

WEATHER DATA

WIND-MILES PER HOUR AND DIRECTION

MONTH *AUGUST 1988*

HOURS

	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	01	02	03	04	05	06	07
1	SW 9	SW 9	S 8	S 9	SW 8	SW 8	SW 7	SW 7	SW 5	SW 6	S 6	SW 7	SW 6	SW 7	SW 7	SW 7	SW 7	SW 6	SW 4	SW 4	W 3	SW 3	SW 4	SW 4
2	SW 6	SW 5	SW 5	SW 7	SW 7	SW 5	SW 5	SW 3	SE 7	SE 9	SE 7	SW 5	SW 8	SW 8	SW 4	SW 4	W 7	SW 5	SW 6	SW 4	SW 5	SW 4	SW 4	SW 5
3	SW 4	SW 5	SW 5	SW 5	SW 5	SW 4	SW 4	SE 5	SE 4	E 1	SE 2	SE 4	SE 5	SE 7	SE 6	SE 6	SW 6	SW 5	SW 6	SW 5	SW 4	SW 5	SW 7	SW 5
4	SW 6	SW 6	SW 7	SW 6	SW 6	SW 6	SW 5	SW 4	SE 4	SE 3	SE 6	SE 5	SW 4	SW 7	SW 5	SW 4	SW 5	SW 5	SW 5	SW 6	SW 6	SW 6	SW 7	SW 6
5	SW 7	SW 7	SW 8	SW 8	SW 7	SE 8	S 9	SE 11	SE 9	S 9	NW 14	NW 10	SW 7	SW 8	SW 10	SW 11	SW 11	SW 11	NW 8	NW 7	NW 8	NW 7	NW 7	NW 6
6	NW 6	NW 7	W 7	SW 8	SW 10	SW 11	SW 10	SW 11	SW 10	SW 7	NW 6	W 4	NW 4	NW 6	NW 7	N 5	N 5	NW 5	NW 5	NW 5	N 4	N 5	NW 5	N 4
7	NE 5	NE 5	E 4	SE 6	S 3	SW 5	SW 5	SW 5	SE 6	SE 5	SE 3	SE 4	SE 3	S 3	S 3	S 4	S 4	S 4	S 4	SW 4	W 5	NW 5	NW 5	NW 3
8	NW 5	W 5	W 7	SW 5	SW 5	SW 6	S 5	SE 7	SE 6	SE 6	SE 8	SE 5	SE 7	SW 6	SW 6	SW 7	SW 7	SW 8	SW 8	SW 9	SW 7	SW 7	SW 7	SW 8
9	SW 8	SW 9	SW 9	SW 9	SW 10	SW 8	SW 9	SW 8	SW 6	SW 5	SW 4	SW 6	SW 5	SW 6	SW 6	NW 6	NW 5	NW 4	NW 4	N 2	NE 2	NE 3	NE 3	NE 4
10	NE 6	NE 8	NE 9	NE 8	NE 9	E 8	SE 8	SE 8	SE 7	SE 7	SE 5	SE 4	E 3	SE 5	SE 7	SE 6	SE 6	SE 5	SE 4	S 2	S 3	SE 3	SE 4	SE 5
11	SW 6	SW 6	SW 7	SW 7	SW 8	SW 7	SW 5	SW 3			POWER		FAILURE				W 4	SW 6	NW 5	NW 6	NW 5	NW 5	NW 4	W 3
12	SW 5	NW 4	SW 4	SW 5	SW 5	SW 6	SW 6	SW 6	SW 5	S 4	SW 4	SW 3	SW 4	SW 5	SW 6	SW 4	SW 6	SW 5	SW 5	SW 7	SW 7	SW 8	SW 7	SW 7
13	SW 7	SW 5	SW 6	SW 7	SW 7	SW 6	SW 5	S 3	SE 6	SE 6	S 4	SE 5	S 5	SW 7	SW 7	SW 5	SW 8	SW 8	SW 10	SW 11	SW 13	SW 12	SW 14	SW 14
14	SW 12	SW 13	SW 11	SW 10	SW 8	SW 10	SW 9	SW 11	SW 11	SW 9	SW 4	SW 12	SW 11	SW 11	SW 12	SW 15	SW 20	SW 12	W 15	NW 14	NW 14	NW 13	NW 11	NW 10
15	NW 5	NW 9	NW 7	SW 7	SW 8	SW 7	SW 9	SW 9	SW 7	SW 6	W 3	W 2	W 2	C	C	C	C	NW 2	NE 3	NE 2	NE 2	NE 3	SE 3	SE 4
16	SE 4	SE 5	SE 3	NE 8	NE 7	SE 5	NE 8	SW 5	SW 9	SW 11	SW 10	SW 5	SW 4	SW 4	SW 5	SW 5	SW 4	SW 5	SW 7	SW 8	SW 9	NW 9	NW 7	SW 9
17	SW 9	SW 9	SW 9	SW 9	SW 9	SW 9	SW 8	SW 7	NE 8	NE 5	NE 5	NE 3	NE 3	NE 4	NE 6	NE 5	NE 3	NE 4	NE 2	NE 2	NE 2	E 1	E 2	NE 2
18	NE 5	NE 7	NE 9	NE 8	NE 9	NE 9	NE 9	NE 8	NE 8	NE 7	NE 6	E 7	NE 6	NE 7	NW 1	NE 4	NE 3	NE 7	SE 7	SE 8	SE 8	SE 6	NE 6	NE 9
19	NE 8	E 10	NE 8	NE 9	NE 8	NE 8	SE 8	E 8	E 8	SE 6	E 6	E 4	E 4	N 5	N 6	NE 6	NE 6	N 5	N 6	N 4	N 5	N 5	N 5	NE 5
20	NE 5	NE 6	NE 5	E 5	SE 3	SE 4	SE 6	W 4	NW 4	W 4	N 4	N 2	N 3	N 6	N 4	N 5	N 5	NE 5	N 5	N 5	N 5	N 5	N 5	NE 7
21	NE 6	NE 7	NE 6	NE 7	E 9	E 8	SE 7	SE 5	SE 4	SE 3	NE 9	NE 8	NE 9	NE 8	NE 6	NE 6	NE 4	NW 6	NE 5	N 5	NW 6	NW 6	NE 6	N 6
22	NE 7	NE 6	NE 6	S 6	SW 6	SW 6	SE 5	SE 5	SE 4	SE 5	SE 8	SE 9	SE 10	SE 11	SE 10	SE 11	SE 11	SE 10	SE 8	SE 7	S 4	SW 5	SW 5	SE 5
23	SE 5	SE 6	SE 6	SE 8	SE 8	SW 8	SW 9	NW 9	NW 11	NW 12	NW 11	NW 12	NW 11	NW 12	NW 10	NW 7	NW 4	NW 5	SW 5	SW 7	SW 6	SW 7	NW 9	NW 7
24	W 10	NW 13	W 12	W 13	W 13	SW 13	SW 11	W 10	W 13	W 12	NW 15	NW 14	NW 15	NW 13	NW 11	NW 11	NW 10	NW 10	NW 11	NW 11	SW 10	NW 10	SW 10	SW 13
25	SW 12	SW 12	SW 15	SW 17	SW 11	SW 15	SW 15	SW 16	NW 14	NW 14	NW 14	NW 16	NW 15	NW 14	NW 10	NW 12	NW 11	NW 11	NW 13	NW 13	NW 12	NW 12	NW 12	NW 11
26	NW 10	NW 11	NW 10	W 11	SW 11	SW 11	SW 10	SW 9	SW 7	SW 6	SW 5	SW 5	S 3	S 5	S 3	S 4	S 4	S 4	SW 5	S 4	SE 4	S 6	SE 6	S 8
27	SW 8	S 7	S 8	S 6	SW 6	SW 5	SW 5	SE 5	SE 3	SE 4	SW 4	SW 7	SW 7	W 8	NW 9	NW 9	NW 10	NW 8	SW 5	SW 4	NE 2	S 3	N 3	N 2
28	NW 6	NW 8	NW 6	NW 7	W 5	SW 5	SW 5	SW 6	SW 7	SW 7	SW 6	SW 7	SW 6	SW 7	NW 7	NW 6	N 6	N 5	N 6	N 6	N 7	N 6	N 6	N 7
29	N 6	N 8	NE 10	NW 8	NW 7	N 9	NW 7	NW 6	NW 5	SW 6	NW 10	NW 10	NW 9	NW 6	NW 6	NW 5	NW 6	NW 5	NW 5	NW 5	NW 5	NW 5	NW 5	NW 5
30	N 6	NW 6	NW 5	NW 5	SW 5	SW 6	SW 6	SW 6	SW 5	SW 4	SW 4	SW 3	C	W 1	C	C	SW 2	SW 4	SW 5	SW 4	SW 5	SW 5	SW 5	SW 5
31	SW	SW	SW	SW	SW	SW	SW	SW	SW	S	S	S	S	S	S	S	S	S	S	SW	SW	S	SE	SE

POINT PELEE NATIONAL PARK

WEATHER DATA

WIND-MILES PER HOUR AND DIRECTION

MONTH SEPTEMBER 68

HOURS

	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	01	02	03	04	05	06	07
1	S 5	SE 7	SE 9	SE 7	SE 8	SE 7	SE 7	E 7	E 8	SE 7	SE 6	SE 6	SE 6	SE 7	SE 7	S 6	S 7	SW 7	SW 6	SW 8	SW 7	SW 6	SW 5	SW 6
2	SW 6	SW 8	SW 6	SW 7	SW 7	SW 7	SW 6	SE 5	SE 4	SE 5	SW 8	SW 7	SW 11	SW 9	SW 9	SW 7	SW 8	SW 8	SW 7	SW 6	SW 7	SW 5	SW 7	SW 7
3	SW 6	SW 5	SW 6	SE 6	SE 6	SE 7	SE 6	SE 8	S 4	S 4	S 4	SE 4	SE 4	SE 3	S 1	S 1	N 2	NW 4	NW 5	N 3	N 2	NW 2	NW 3	NW 3
4	NW 4	NW 5	NW 9	NW 8	NW 6	SW 8	SW 7	SW 8	SW 7	SW 10	SW 13	NW 14	NW 7	NW 7	NW 10	NW 12	NW 13	NW 14	NW 11	N 13	NW 10	NW 11	NW 11	NW 10
5	NW 11	NW 11	NW 12	NW 10	NW 8	NW 9	NW 8	NW 9	NW 7	NW 7	NW 5	NW 5	NW 6	NW 9	NW 8	NW 8	NW 7	NW 7	NW 7	NW 7	NW 7	NW 6	NW 8	NW 6
6	NW 7	NW 7	NW 7	NW 7	NW 6	SW 6	SW 7	SW 6	SW 7	NW 6	NW 7	NW 7	NW 7	NW 4	NW 5	NW 6	NW 6	NW 5	NW 5	SW 7	SW 9	SW 7	N 4	N 3
7	NW 6	NW 5	SW 6	SW 7	SW 7	SW 7	SW 7	SW 5	SW 4	S 3	S 3	S 4	SE 5	SE 5	SW 8	SW 9	SW 8	SW 7	SW 8	SW 7	SW 7	SW 7	SW 8	SW 8
8	SW 8	SW 8	SW 8	SW 7	SW 9	SW 7	SE 7	SE 6	SE 6	SE 6	SE 5	SE 7	SW 8	SW 8	SW 9	SW 10	SW 12	SW 12	SW 11	SW 11	SW 10	SW 10	SW 10	SW 12
9	SW 12	SW 10	SW 8	SW 9	SW 8	SW 9	SW 7	SW 5	SW 5	SW 4	SW 2	W 2	NW 3	W 3	W 3	W 3	NW 4	NW 5	NW 5	NW 5	W 6	NW 5	NW 7	NW 5
10	NW 6	NW 7	SW 7	SW 8	SW 9	SW 8	SW 7	SW 5	SW 3	SW 3	W 4	NW 3	NW 3	NW 4	NE 5	NE 3	NE 5	NE 4	NE 5	NE 7	E 6	E 6	E 4	E 4
11	SE 7	SE 8	SE 8	SE 9	SE 8	SE 4	SE 9	SE 9	SE 9	SE 7	SE 9	SE 9	SE 10	SE 9	SE 7	SE 7	SE 8	SE 5	SE 5	SE 5	SW 5	SE 5	S 4	S 4
12	SE 4	SE 7	SE 7	SW 7	S 6	NW 4	SE 4	SE 5	SW 8	S 6	SW 10	SW 6	SW 8	SW 7	SW 6	SW 7	SW 9	SW 8	SW 10	SW 5	NW 7	NW 7	NW 10	NW 9
13	NW 9	N 10	N 9	NW 8	NW 8	NW 6	SW 7	NW 9	N 9	NW 2	NW 3	NW 5	NW 7	NW 6	NW 4	NW 6	NW 8	NW 7	NW 6	NW 6	NW 7	NW 5	NW 6	NW 7
14	SW 9	SW 9	W 8	SW 8	SW 9	SW 10	SW 8	NW 7	NW 6	N 4	N 4	N 5	NE 8	NE 11	NE 12	NE 12	NE 11	NE 11	NE 10	NE 10	NE 7	NE 5	N 4	N 5
15	E 8	E 11	E 11	E 11	NE 10	E 11	SE 11	E 10	E 11	NE 11	E 11	E 12	SE 12	E 12	SE 13	SE 14	SE 13	SE 13	SE 13	SE 12	SE 12	SE 13	SE 12	SE 12
16	SE 11	SE 12	SE 12	SE 12	SE 10	SE 11	SE 9	E 10	E 8	E 6	SE 6	SE 9	SE 8	S 9	SW 9	SW 10	SW 10	SW 8	SW 10	SW 9	SW 7	SW 9	SW 9	SW 8
17	SW 9	SW 9	SW 8	SW 9	SW 7	SW 8	SW 6	SW 6	SW 6	SW 6	SW 7	SW 7	SW 8	SW 8	SW 8	SW 8	SW 9	SW 10	SW 10	SW 12	SW 9	SW 5	SW 5	SW 5
18	SW 6	SW 7	SW 7	SW 7	SW 6	SW 6	SW 5	SW 5	SW 5	NW 10	SW 3	SW 5	SW 6	SE 4	SE 3	SW 3	SW 6	SW 6	SW 5	S 5	S 4	SE 5	SE 5	SE 7
19	SE 6	SE 6	SE 7	SE 8	SE 8	S 6	SE 8	SE 8	SE 9	SE 10	SE 13	SE 13	SE 13	SW 14	SW 15	SW 14	SW 19	SW 15	SW 9	SW 12	SW 13	SW 17	SW 17	SW 19
20	SW 19	SW 17	SW 17	SW 16	SW 17	SW 14	SW 16	SW 16	SW 13	SW 15	NW 13	NW 14	NW 14	NW 14	NW 12	NW 12	NW 9	NW 10	NW 10	NW 12	NW 10	NW 9	NW 10	NW 10
21	NW 10	NW 10	NW 10	NW 7	NW 8	NW 9	NW 7	NW 5	NW 5	NW 6	NW 5	NW 5	NW 5	NW 5	NW 4	NW 3	N 3	N 2	N 2	NE 2	SW 6	SW 7	SW 7	SW 5
22	SW 6	SW 5	SW 6	SE 5	SE 7	SE 6	SE 6	SE 10	SE 11	SE 8	SE 8	SE 5	SE 6	SE 10	SW 11	SW 16	NW 11	SW 8	SW 8	SW 9	NW 8	NW 8	NW 10	NW 9
23	NW 7	NW 10	NW 9	NW 10	NW 8	NW 8	NW 8	W 7	W 7	NW 7	NW 8	NW 5	NW 4	NW 5	NW 7	NW 7	NW 7	N 6	NE 6	N 6	N 6	N 6	N 6	N 5
24	NE 5	NE 6	NE 8	NE 9	NE 9	NE 8	NE 10	NE 11	E 9	E 9	E 6	E 6	SE 7	E 6	E 4	N 5	N 5	N 7	N 6	N 5	N 6	N 6	N 6	NE 5
25	NE 4	NE 6	NE 7	SE 3	SW 5	SW 5	SW 5	SW 6	SW 6	SW 4	SW 4	SW 5	SW 5	SW 4	SW 5	W 5	W 5	W 5	NE 6	NE 7	NE 8	NE 6	NE 5	NE 6
26	NE 7	NE 5	SE 6	SE 7	SE 7	SE 7	SE 6	SE 5	SE 5	SE 4	SE 5	SE 7	SE 7	SE 4	SE 4	S 6	SW 8	SW 10	SW 11	SW 10	SW 10	SW 7	SW 7	SW 7
27	SW 8	SW 11	SW 11	SW 10	SW 8	SW 7	SW 6	SW 5	SW 4	SW 2	SW 3	SW 4	SW 5	SW 4	SW 5	N 5	NE 11	NE 12	NE 12	NE 13	NE 13	NE 9	NE 10	NE 12
28	NE 11	NE 11	NE 13	NE 13	NE 11	NE 12	NE 13	NE 13	NE 12	E 14	NE 15	E 16	NE 16	NE 15	E 15	SE 15	SE 15	SE 14	SE 13	SE 13	SE 13	SE 11	SE 10	E 9
29	SE 8	SE 8	E 8	E 7	E 8	E 7	E 7	E 7	NE 7	SE 5	E 9	SE 9	SE 7	SE 7	SE 5	S 5	SE 6	SE 4	S 3	S 4	SW 4	SW 5	SW 4	SW 4
30	SW 4	SW 4	SW 4	SW 5	SW 5	SW 5	SW 4	SW 4	S 3	S 3	S 5	SW 6	SW 5	SW 5	SW 4	SW 8	SW 8	SW 6	SW 4	SW 3	SW 4	SW 4	SW 4	SW 6
31																								

APPENDIX II

```
CHARACTER*3 DIR(31,24)
CHARACTER*10 ONE, TWO ,UNIT
REAL ANG(31,24),SPEED(31,24),CON
INTEGER IY,IMON,DATE
DIMENSION NUMDAY(12)
DATA ANG/744*999.9/
DATA NUMDAY/31,28,31,30,31,25,31,31,30,10,30,31/
WRITE(6,*) 'ENTER DATA FILE TO CONVERT'
READ(5,25) ONE
WRITE(5,*) 'ENTER OUTPUT DATA FILE'
READ(5,25) TWO
FORMAT(A10)
OPEN(6,FILE=ONE)
OPEN(8,FILE=TWO,STATUS='NEW')
WRITE(6,*) 'ENTER STARTING DATE AS YEAR,MONTH'
READ(5,*) IY ,IMON
IF(MOD(IY,4) .EQ. 0) THEN
NUMDAY(2)=29
END IF
IF (IMON.LT.0 .OR. IMON.GT.12) THEN
WRITE(*,*) 'Month is not valid'
GOTO 200
END IF
WRITE(6,*) 'ENTER WIND SPEED UNIT(KM,MILES,KNOTS)'
READ(5,25) UNIT
 IF(UNIT .EQ. 'KM') THEN
    CON=0.538
    ELSEIF(UNIT .EQ. 'MILES') THEN
    CON=0.869
    ELSEIF(UNIT .EQ. 'KNOTS') THEN
    CON=1.0
    ELSE
    GOTO 75
    ENDIF
K=NUMDAY(IMON)
READ (5,777) ((SPEED(I,J) , DIR(I,J), J=1,24),I=1,K )
FORMAT (12(F2.0,A3),/,12(F2.0,A3))
DO 100 I=1,K
DO 100 J=1,24
SPEED(I,J)=SPEED(I,J)*CON
IF (DIR(I,J).EQ.'  N') ANG(I,J) = 0.0
IF (DIR(I,J).EQ.'NNE') ANG(I,J) = 22.5
IF (DIR(I,J).EQ.' NE') ANG(I,J) = 45.0
IF (DIR(I,J).EQ.'ENE') ANG(I,J) = 67.5
IF (DIR(I,J).EQ.'  E') ANG(I,J) = 90.0
IF (DIR(I,J).EQ.'ESE') ANG(I,J) = 112.5
IF (DIR(I,J).EQ.' SE') ANG(I,J) = 135.0
IF (DIR(I,J).EQ.'SSE') ANG(I,J) = 157.5
IF (DIR(I,J).EQ.'  S') ANG(I,J) = 180.0
IF (DIR(I,J).EQ.'SSW') ANG(I,J) = 202.5
```

```
IF (DIR(I,J).EQ.' SW') ANG(I,J) = 225.0
IF (DIR(I,J).EQ.'WSW') ANG(I,J) = 247.5
IF (DIR(I,J).EQ.'  W') ANG(I,J) = 270
IF (DIR(I,J).EQ.'WNW') ANG(I,J) = 292.5
IF (DIR(I,J).EQ.' NW') ANG(I,J) = 315.0
IF (DIR(I,J).EQ.'NNW') ANG(I,J) = 337.5
IF (ANG(I,J).GT.360.) THEN
WRITE(6,*) 'BOGUS DATA',DIR(I,J)
ENDIF
CONTINUE
DO 200 I= 1,K
DATE=IY*10000+IMON*100+1
WRITE(6,500) DATE,(SPEED(I,J),ANG(I,J),J=1,24)
CONTINUE
FORMAT(' ',I8,' ',6(4(F5.1,2X,F5.1,3X)/,'              '))
STOP
END
```

REFERENCES

American Society for Testing and Materials. 1963. Standard Method for Grain Size Analysis of Soils. Designation D 422-63. p95-106.

Bagnold,R.A. 1946. Motion of Waves in Shallow Water. Proceedings Royal Society. London. A., 187. p1-15.

Bakker,W.T. 1974. Sand Concentration in an Oscillatory Flow. Proceedings, 16th Coastal Engineering Conference. p1129-1148.

Bishop,C.T. 1983. Comparison of Manual Wave Prediction Models. Journal of Waterway, Port, Coastal and Ocean Engineering.,109. p1-17.

Bishop,C.T. and Donelan,M.A. 1985. Waves and Wave Forecasting. National Water Research Institute. Contribution 85-138. C.C.I.W. Burlington.

Blatt,H., Middleton,G. and Murray,R. 1980. Origin of Sedimentary Rocks. Prentice Hall, Incorporated. New Jersey. p135.

Bloesch,J. 1982. Inshore-Offshore Sedimentation Differences Resulting from Suspension in the Eastern Basin of Lake Erie. Canadian Journal Fish and Aquatic Sciences.39. p748-759.

Bloesch,J. and Burns,N. 1980. A Critical Review of Sediment Trap Technique. Schweiz. Z. Hydrol., 42. p15-55.

Bowen,A.J. and Doering,J.C. 1984. Nearshore Sediment Transport: Estimates From Detailed Measurements of the Nearshore Velocity Field. Vol.2, Proceedings,19th Coastal Engineering Conference. p1703-1714.

Bukata,R.P., Haras, W.S. and Bruton, J.E. 1975. The Application of ERTS-1 Digital Data to Water Transport Phenomena in the Point Pelee Rondeau Area. Veh. Int. Verein. Limnol., 19. p168-178.

Buller,A.T. and McManus,J. 1976. Fluctuations of Suspended Sediment in Estuaries. A Descriptive Review; Publication of Tay Estuary Research Centre,3. p39.

Clark,W.A.V. and Hosking,P.L. 1986. Statistical Methods for Geographers. Wiley and Sons, Toronto. p266.

Coakley,J.P. 1972. Nearshore Sediment Studies in Western Lake Erie. Proceedings,15th Conference Great Lakes Research, Internat. Ass. GLR. p330-343.

Coakley,J.P. 1978. Processes in Sediment Deposition and Shoreline Changes in the Point Pelee Area, Ontario. Inland Waters Directorate, Sci,. Series 79. 76p.

Coakley,J.P. 1980. Postglacial Evolution and Modern Processes at Point Pelee, Lake Erie. The Coastline of Canada. S.B. McCann(ed). Geological Survey of Canada, Ottawa. p429-437.

Coakley,J.P. and Cho,H.K. 1972. Shore Erosion in Western Lake Erie. Proceedings,15th Conference Great Lakes Research, Internat. Ass. GLR. p344-360.

Dally,W.R. and Dean,R.G. 1984. Suspended Sediment Transport and Beach Profile Evolution. Journal of Waterway, Port, Coastal and Ocean Engineering., 110, p15-33.

Deigard,R., Fredsoe,J. and Broker Hedegaard,I. 1986. Suspended Sediment in the Surf Zone. Journal of Waterway, Port, Coastal and Ocean Engineering.,112. p115-128.

Donelan,M.A. 1984. Application of A Simple Numerical Wave Prediction Model to Lake Erie. Journal of Geophysical Research.,89, no C3, p3586-3592.

Eadie,B., Chambers,R.L., Gardner,W.S. and Bell,G.L. 1984. Sediment Trap Studies in Lake Michigan: Resuspension and Chemical Fluxes in the Southern Basin. Journal of Great Lakes Research.,10. p307-321.

East,K.M. 1976. Shoreline Erosion, Point Pelee National Park, a History and Policy Analysis. Parks Canada. National Resources Division Working Paper, Ontario Region. 66p.

Einstein,H.A. 1950. The Bedload Function for Sediment Transportation in Open Channels. U.S. Dept. Agric. S.C.S. Tech Bulletin no 28.

Fairchild,J.C. 1984. Longshore Transport of Suspended Sediment. Proceedings,20th Coastal Engineering Conference. p1069-1087.

Fredsoe,J.,Anderson,O.H.and Silberg,S. 1985. Distribution Of Suspended Sediment In Large Waves. Journal of Waterway, Port, Coastal and Ocean Engineering. p1041-1059.

Gardner,W.D. 1977. Fluxes, Dynamics and Chemistry of Particulates in the Ocean. Ph.D. thesis. MIT/Woods Hole Oceanogr. Inst. 405p.

Gardner,W.D. 1980. Field Assessment of Sediment Traps. Journal Marine Research.,38. p41-52.

Grant,W.G. and Glenn,S.M. 1983. Continental Shelf Bottom Boundary Layer Model, Volume 1: Theoretical Model Development. Woods Hole Oceanographic Institution.

Hargrave,B.T. and Burns,N. 1979. Assessment of Sediment Trap Collection Efficiency. Limnol. Oceanogr.,24. p1124-1136.

Hattori,M. 1969. The Mechanics of Suspended Sediment Due to Standing Waves. Coastal Engineering in Japan.,12. p69-81.

Hawley, N. 1988. Flow in Cylindrical Sediment Traps. Journal of Great Lakes Research.,14(1).p76-88.

Horikawa,K. and Wantabe,A. 1967. A Study of Sand Movement Due to Wave Action. Coastal Engineering in Japan.,10. p.39-57.

Horvath,T. 1987. Basic Statistics for Behavioural Sciences.Little, Brown and Co. Toronto.456p.

Inman,D.L., Zampol,J.A., White,I.E., Hanes,D.M., Waldorf,B.W. and Kastens,K.A. 1980. Field Measurements of Sand Motion in the Surf Zone. Proceedings, 17th Coastal Engineering Conference. p1215-1233.

Jonsson,I.G. 1966. Wave Boundary Layers and Friction Factors. Proceedings, 10th Coastal Engineering Conference. p127-148.

Justensen,P., Fredsoe,J. and Deigaard,R. 1986. The Bottleneck Problem for Turbulence in Relation to Suspended Sediment in the Surf Zone. Proceedings,20th Coastal Engineering Conference. p1225-1239.

Kajiura,K. 1968. A Model of the Bottom Boundary Layer in Water Waves. Bull. Earthquake Res. Ins. University Tokyo., 46. p75-123.

Kamphuis,J.W. 1972. Progress Report on Point Pelee Beach Study (1970 and 1971) and Marentette Beach Protection Programme. Report DLFS - 3 to Ontario Ministry of Lands and Forests. 77p.

Kana,T. 1986. Surf Zone Measurements of Suspended Sediments.Proceedings, 20th Coastal Engineering Conference. p1725-1741.

Katoh,K., Tanaka,N. and Irie,I. 1984. Field Observation on Suspended Load in the Surf Zone.Proceedings,19th Coastal Engineering Conference. p1846-1862.

Kennedy,J.F. and Locher,F.A. 1972. Sediment Suspension by Water Waves. Waves on Beaches. R.E.Meyer(ed). Academic Press, N.Y. p249-295.

Kindle,E.M. 1938. Erosion and Sedimentation at Point Pelee, Ontario. 42nd Annual report of Ont. Dept. of Mines. pt.2. p1-22.

King,C.A.M. 1966. Techniques in Geomorphology. Edward Arnold Publishers Ltd. London. 342p.

Komar,P.D. 1983. Handbook of Coastal Processes and Erosion. CRC Press, Inc. Florida. p1-18.

Kovacs,M. 1987. Spatial Response to Shoreline Processes: South Tip Beach, Point Pelee. Unpublished B.A. Thesis. Department of Geography, University of Windsor.

Larsen,L.H., Sternberg,R.W., Shi,N.C., Marsden,M.A.H. and Thomas,L. 1981. Field Investigations of the Threshold of Grain Motion by Ocean Waves and Currents. Marine Geology., 42. p105-132.

Lee,D.Y., Lick,W. and Kang,S.W. 1981. The Entrainment and Deposition of Fine Grained Sediments in Lake Erie. Journal of Great Lakes Resources., 7. p224-233.

Lewis,C.F. 1966. Sedimentation Studies of Unconsolidated Deposits in the Lake Erie Basin. unpub. Ph.D. thesis, Dept. of Geol. Science, University of Toronto. 135p.

Lick,W. and Kang,S.W. 1987. Entrainment of Sediments and Dredged Materials in Shallow Lake Waters. Journal of Great Lakes Research., 13. p619-627.

Liu,P.C.,Schwab,D.J. and Bennett,S.R. 1984. Comparison of a Two-Dimensional Wave Prediction Model with Synoptic Measurements in Lake Michigan. Journal of Physical Oceanography., 14. p1514-1518.

Madsen,O.S. and Grant,W.D. 1976. Description of Sediment Transport by Waves. Proceedings,15th Coastal Engineering Conference. p1093-1112.

Ministry of Fisheries and Oceans. 1987. Map of Pelee Passage to Detroit River. Canadian Hydrographic Service, L/C 2123.

Namikas,S. 1988. A Spatial-Temporal Analysis of Beach Morphology and the Effect of Storm-Wave Generated Longshore Sediment Transport: Northeast Beach, Point Pelee, Ontario. Unpublished B.A. Thesis. Department of Geography, University of Windsor.

Nielsen,P. 1984. Field Measurements of Time Averaged Suspended Sediment Concentrations Under Waves. Proceedings,20th Coastal Engineering Conference. p51-72.

Nummedal,D., Sonnenfeld,D.L. and Taylor,K. 1981. Sediment Transport and Morphology at the Surf Zone of Presque Isle, Lake Erie, Pennsylvania. Marine Geology., 60. p99-122.

Parks, Canada. 1988. Recorded Hourly Wind Data for July, August, September and October.

Pethick,J. 1984. An Introduction to Coastal Geomorphology. Edward Arnold Publishers Ltd. London. 260p.

Rathke,D.E., Bloesch,J. Burns,N.M. and Rosa,F. 1981. Settling Fluxes in Lake Erie (Canada) Measured by Traps and Settling Chambers. Verh. Internat. Verein. Limnol., 21.p383-388.

Rayner,J.N. 1971. An Introduction to Spectral Analysis. Pion,Ltd. Great Britian. 174p.

Rosa,F. 1985. Sedimentation and Sediment Resuspension in Lake Ontario. Journal of Great Lakes Research., 11. p13-25.

Rukavina,N.A. and Zeman,A.J. 1987. Erosion and Sedimentation Along a Cohesive Shoreline-The North-Central Shore of Lake Erie. Journal of Great Lakes Research.,13. p202-217.

SAS Institute, Inc. 1985. Box 8000, Cary, North Carolina. 27511.

Schwab,D.J., Bennett,J.R. and Lynn,E.W. 1984. A Two-Dimensional Lake Wave Prediction System. NOAA Technical Memorandum ERL GLERL-51. Great Lakes Environmental Research Laboratory. Michigan.

Shaw,J.R. 1978. Coastal Response at Point Pelee, Lake Erie. Manuscript Report Series no.4. Ocean and Aquatic Sciences. CCIW. Burlington. 81p.

Skafel,M.G. 1975. Longshore Sediment Transport at Point Pelee; Environment Canada, Canada Centre for Inland Waters, unpub. report.

Skafel,M.G. and Krishnappan,B.G. 1984. Suspended Sediment Distribution in Wave Field. Journal of Waterway, Port, Coastal and Ocean Engineering.,110. p215-229.

Staub,C., Jonsson,I. and Svendsen,I.A. 1984. Variation of Sediment Suspension in Oscillation Flow. Proceedings.19th Coastal Engineering Conference. p2310-2321.

Sternberg,R.W., Shi,N.C. and Downing,J.P. 1984. Field Investigations of Suspended Sediment Transport in the Nearshore Zone. Proceedings,19th Coastal Engineering Conference. p1783-1797.

St.Jacques,D. and Rukivina,N.A. 1976. Lake Erie Nearshore Sediments, Port Burwell to Point Pelee, Ontario. Canada Centre for Inland Waters. unpubl. report.

Trenhaile,A.S. and Dumala,R. 1978. The Geomorphology and Origin of Point Peiee, Southwestern Ontario. Canadian Journal of Earth Science. 15. p962-970.

Vanoni,V.A. 1964. Caltech W.M. Keck Lab. Hydraulics Report. KH-R-1.

vanRijn,L.C. 1986. Sedimentation of Dredged Channels by Currents and Waves. Journal of Waterway, Port Coastal and Ocean Engineering. p541-559.

Vincent,G.E. 1958. Contribution to the Study of Sediment Transport on A Horizontal Bed Due to Wave Action. Proceedings, 6th Coastal Engineering Conference. p326-354.

Vongvisessomjai,S. 1986. Profile of Suspended Sediment Due to Wave Action. Journal Waterway, Port, Coastal and Ocean Engineering., 112. p35-53.

Winer,B.J. 1971. Statistical Principles in Experimental Design., Second Edition, McGraw-Hill Book Co., N.Y.

VITA AUCTORIS

Name:	Lorie Ann Libby	
Birth Date:	November 5, 1964	
Birth Place:	Chatham, Ontario	
Education:	Ridgetown District High School Ridgetown, Ontario	1983
	Honours Bachelor of Arts Geography (Resource Management) University of Windsor	1987
	Bachelor of Education University of Windsor	1989
	Master of Arts Geography University of Windsor	1990